VIBRATION MEASUREMENTS ON MODULAR CAUSEWAY FERRY (MCF)

Prepared For:

LAKE SHORE, INC.
AN OLDENBURG GROUP COMPANY
P.O. BOX 809
IRON MOUNTAIN, MI 49801

Prepared Under:

LSI PURCHASE ORDER 109903

NKF REPORT NO. 9602-01/1

MAY 1995

NKF PUBLICATIONS CONTROL NO. B950201

NKF Engineering, Inc. • 4200 Wilson Boulevard, Suite 900 • Arlington, Virginia 22203 • (703) 358-8600

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ACKNOWLEDGEMENT

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1.0 INTRODUCTION

Lake Shore Incorporated (LSI) was the prime contractor to the U.S. Army in the production of the Modular Causeway Ferry (MCF). NKF Engineering, Inc. (NKF) was contracted by LSI under Purchase Order No. 109903, dated 23 January 1995, to conduct first article vibration measurements under operational conditions.

Translational and torsional vibration measurements were recorded while underway in the James River near Ft. Eustis on 11 May 1995. The test was conducted in accordance with the test procedure (Appendix A) and References 1, 2, and 3. This document provides a final report on the survey including: procedure, instrumentation used, calibration method, and a summary of all significant results.

2.0 OBJECTIVES

To measure and record the vibration characteristics of one MCF propulsion module during full load, full speed sea trials in accordance with References 1, 2, and 3. Vibration characteristics of the propulsion system shall meet the requirements of Reference 1.

3.0 MCF CHARACTERISTICS

The MCF is defined by LSI Drawing E03155, and the MCF powered module is defined by LSI Drawing E02843.

General Characteristics: The MCF is a modular self-propelled ferry. In the tested configuration, it was 320 feet long x 24 feet wide x 4.5 feet deep. General construction is of ISO compatible steel modules joined by USN standard flexor and shear connectors.

Cargo capacity of the MCF in the test configuration is specified as 350 short tons. Maximum speed is specified as 6 knots at full load.

Propulsion modules (40 feet x 8 feet x 4.5 feet) are located aft; one port, one starboard. Propulsion is provided by a Detroit Diesel 8V92TA engine operating through a gearbox to a flush-mounted 360-degree steerable waterjet thruster. A single 4 feet x 6 feet Control Cab (CC) is located on one of the propulsion modules.

4.0 TECHNICAL APPROACH

- Determine the longitudinal vibration characteristics of the propulsion system with an accelerometer measuring the longitudinal motion of the waterjet foundation. Vibratory motions of the engine foundation to be measured with an accelerometer mounted in the vertical direction.

- Determine the torsional vibration characteristics of the propulsion system with a rotational velocity transducer, or torsiograph mounted to the free end of the engine. Dynamic angular displacements at the free end of the engine will be used along with the torsional analysis (Reference 4) to determine maximum dynamic stresses and torque across the gears.

- Measure hull vibrations at the stern of the propulsion module in three principle axes. Vibratory motions will be recorded in acceleration units during trials and converted to velocity or displacement units as necessary. Vibratory motions in the CC in the principle direction of motion will also be measured. Additionally, vibration at any location observed to be excessive or potentially damaging will also be measured.

5.0 PROCEDURE

5.1 INSTALLATION PROCEDURE

An adapter shaft to attach the torsiograph to the free end of the propulsion engine crankshaft was provided by LSI. The adapter was designed to interface between the free end of the engine at the crankshaft and the rotational velocity transducer (torsiograph).

Twelve-volt DC power from the propulsion module batteries was used to power the amplifiers and recorder.

The test equipment installed consisted of sensors, signal cable, signal conditioners, calibration equipment, and a recording device. The table below lists the data acquisition system used to complete the test.

QTY	DESCRIPTION	MANUFACTURER	MODEL NO.
6	Accelerometer	Wilcoxon Research	766
1	Accelerometer	PCB Piezotronics	328 A51
1	Rotational Velocity Transducer (Torsiograph)	Knopfle-Stein	s/n 11
1	Variable Reluctance Pickup (Event Marker)	Electro Corporation	3030AN606909
1	12-Channel Amplifier	PCB Piezotronics	483B07
1	21-Channel FM Tape Recorder	TEAC	XR-7000
1	2-Channel Spectrum Analyzer	Ono Sokki	CF-350
1	Accelerometer Calibrator	PCB Piezotronics	394B06

Sensors were installed in the following locations/orientations. The orientation of the accelerometer in the control cab was determined by comparison measurements while operating near full power. The location chosen for the extra accelerometer was the top of the water pump because of low frequency displacements noted at this location during operating conditions. Locations of transducers are shown in Figure 1.

ITEM NO.	QTY REQUIRED	EQUIPMENT DESCRIPTION	LOCATION	MEASUREMENT DIRECTION
1	1	Accelerometer	Waterjet foundation	Fore/Aft
2	1	Accelerometer	Diesel engine foundation	Vertical
3	3	Accelerometer	Stern of propulsion module	Fore/Aft, Athwartship, Vertical
4	1	Accelerometer	Control cab	Athwartship
5	1	Torsiograph	Free end of diesel engine	Torsional
6	1	Event Marker	Adjacent to main shaft	Shaft Revolutions
7	1	Accelerometer	Top of water pump	Athwartship

The accelerometer mounting blocks were installed in proper locations using quick set epoxy, taking care to ensure that the threaded holes and/or studs were in the proper orientation for gage attachment.

The torsiograph was attached to the adapter located on free end of propulsion engine at the crankshaft centerline.

The event marker target was installed on the propulsion shaft near the water pump using circle clamps. The event marker pickup was attached adjacent to target in a secure manner.

Signal cables were attached to all transducers and connected to an amplifier/power supply, where necessary, and then directly to the tape recorder. Separate cables were used to monitor the tape recorder outputs with the two-channel analyzer.

5.2 TEST PROCEDURE

The approved test procedure is included in Appendix A. The test included recording several minutes of data at constant RPM in approximately 75 RPM increments from idle to full speed. In addition, a sweep was recorded in which the RPM was slowly increased over the full operating range. Crash ahead, crash astern, and hard turn maneuvers were also recorded.

The logsheets showing equipment gains and settings are also presented in Appendix A. An instrumentation block diagram for data recording is shown in Figure 2.

6.0 CALIBRATION

6.1 LABORATORY CALIBRATION

The accelerometers and accelerometer calibrator were calibrated at an independent laboratory within 6 months prior to the test. These calibrations demonstrated accuracies to within acceptable tolerances, traceable to the National Institute of Standards and Technology (NIST). The torsiograph was calibrated at NKF's laboratory within 6 months prior to the test. Calibration data and certifications are included in Appendix B.

6.2 FIELD CALIBRATION

A circuit check and physical calibration of the accelerometers were conducted using the accelerometer calibrator to subject the accelerometer to a 1.0 gravity RMS sine motion at a frequency of 80 Hz. The accelerometer output signal passed through all cabling and amplifiers used during the test. The amplifier output was recorded on tape for about 30 seconds. A block diagram of the calibration configuration is shown in Figure 3.

7.0 DATA REDUCTION

The instrumentation used to perform the data reduction/analysis consisted of the following:

QTY	MANUFACTURER	MODEL	DESCRIPTION
1	TEAC	XR-7000	FM Tape Recorder
1	Hewlett-Packard	3566/67A	Spectrum Analyzer
1	Generic	486DX66	Personal Computer (PC)

During data reduction, the conversion from volts to engineering units was calculated using the measured field calibration data from the transducers, signal conditioning gain settings, and recording equipment sensitivity settings.

Using these conversion constants, the constant speed operational data recorded on the tape was then digitized and stored as averaged frequency data by the spectrum analyzer. A flat-top antileakage window was used, and approximately 2 minutes of data was averaged for each constant speed condition. The frequency domain data was acquired and stored in both 50 Hz and 400 Hz full-scale ranges. In the 50 Hz data, frequency resolution was 0.25 Hz. Frequency resolution was 1.0 Hz in the 400 Hz data. These spectra were then transferred to the PC which generated vibratory "waterfall" plots. The accelerometer data was plotted in both acceleration and velocity units where the velocity spectra were obtained by frequency domain integration. The torsiograph data was simalarly processed and presented in units of degrees (angular displacement).

For the data recorded during the speed sweeps, waterfall-type plots were generated automatically by the spectrum analyzer. The spectra in the sweep waterfalls are instantaneous spectra (from a single time record) and are presented at much closer and uniformly spaced RPM increments than the constant speed runs. These spectra were plotted in units of velocity with the exception of the torsiograph, which was plotted in degrees.

8.0 RESULTS

The waterfall plots resulting from the steady speed runs are shown in Appendices C and D. Appendix C contains spectra in acceleration units over 50 Hz and 400 Hz analysis

ranges, while Appendix D shows the same spectra in velocity units. Appendix E shows the results of the speed sweeps in velocity units. Appendix F contains waterfalls and speed sweep plots for the torsiograph data.

8.1 HULL AND STRUCTURAL VIBRATION

At present, there exists a wide variety of standards, both commercial and government, and methods of interpreting those standards as to what are acceptable levels of vibration for habitation. The levels of vibration for the hull location and the control cab as shown in Appendices C, D, and E are low for propulsion spaces on ships and would be acceptable by all known habitability criteria. Reference 5 is indicative of current vibration specifications. It is a draft update of existing ISO standards reflecting current analysis techniques and hardware. This guideline determines suitability for habitation as an RMS broadband (1-100 Hz) velocity term. It is not intended to predict machinery reliability, which would, in general, be expected to withstand higher levels of vibration than are suitable for habitation. By Reference 5, vibration levels are divided into three categories: acceptable (<87 mils/sec RMS), marginally acceptable (<197 mils/sec RMS), and not acceptable.

While the control cab is the only normally inhabited space on the ferry, the stern measurement location also provides information regarding overall hull girder motions in a location where these motions would be expected to be large. These four gages were all found to be in the acceptable range for habitability under normal operating conditions at and near full speed.

8.2 PROPULSION SYSTEM VIBRATION

The longitudinal vibration requirements of MIL-STD-167-2 apply to propulsion systems which utilize conventional screw-type propellers which transmit thrust through the shaft to a hull-mounted thrust bearing. In this case, the mass-elastic system consisting of the propeller, a long section of shafting, and the thrust bearing and assembly and foundation can be excited at resonance from the longitudinal alternating forces generated by the propeller.

On the MCF, the water jet transmits thrust directly to the hull, which is a stiffer path than found in conventional systems. In addition, the large masses of the screw-type propeller and shafting are not present.

The accelerometer mounted at the base of the water jet showed low levels of vibration in the longitudinal direction. While this is not a space normally inhabited, it is informative to note that the levels of vibration at this location were within marginally aceptable limits for habitation discussed in Section 8.1. In addition, the measured motions were well below allowable displacements as specified by MIL-STD-167-2 for conventional propulsion systems.

Additional accelerometers were also located at the base of the port side mount for the diesel engine (vertical) and the top of the water pump (athwartship). The engine location was chosen because it would provide information about engine-induced vibration in the vessel, and the water pump location was chosen because of relatively large low frequency vibrations noted at that location during operating conditions.

Reference to all of the accelerometer data shows a 22 Hz nartural frequency which appears to be a global hull mode, as it appears in nearly every accelerometer. The highest measured level for this mode was at the diesel engine mount at 2,220 RPM. However, this mode does not appear to be excited by an engine order at this speed, but rather by the second order of the impeller. A local resonance was also noted at the top of the water pump at around 10 Hz. This appears to be a side-to-side rocking of the cantilever mounted pump structure. The excitation appears to be first order rotation of the pump impeller. The motion can also be seen in the control cabin and stern athwartship gage data. The levels for either resonance do not appear to be cause for alarm, however the water pump enters the 10 Hz resonance near 2,100 RPM (full speed), and from this standpoint, it might be desirable to stiffen either the pump mounting base or add a top brace to move this resonance above the normal operating range.

Review of the torsiograph steady speed and sweep data shows no indication of any significant torsional criticals throughout the operating range. Vibratory stress and torque across the gear sets is only significant and can only be calculated when measurement data is available at the torsional critical condition. The propulsion system is adequate for torsional vibration by the MIL-STD-167-2 criteria.

The presence of vibration data at pump impeller rotational rate and harmonics both in the accelerometer data and the torsiograph data was unexpected. Although the measured levels are low, it is possible that the vibration is caused by an imbalance in the impeller or a bent or otherwise inconsistent impeller blade.

9.0 CONCLUSIONS

It is concluded from review of the recorded test data that the MCF is adequate for vibration of the propulsion system and hull structure by the specification criteria as applicable and by other recognized commercial and government vibration standards.

10.0 REFERENCES

1. MIL-STD-167-2, "Mechanical Vibrations of Shipboard Equipment (Reciprocating Machinery and Propulsion System and Shafting), Types III, IV, and V," dated 1 May 1974.

2. SNAME Technical & Research Code C-1, "Code for Shipboard Vibration Measurement," dated January 1975.

3. SNAME Technical & Research Code C-4, "Local Shipboard Structures and Machinery Vibration Measurements," dated December 1976.

4. Detroit Diesel Corporation Engineering Analytical Report I3R-011-11580-01 "Torsional Vibration Analysis of an 8V-92TA Engine Driving an Omnithruster Model HCT700BD Through a Seawall Z-Drive Gear Box for Inland DDA: Modular Causeway," TAR 3231A

5. International Standard ISO 6954 (1995 proposed), Part 2.

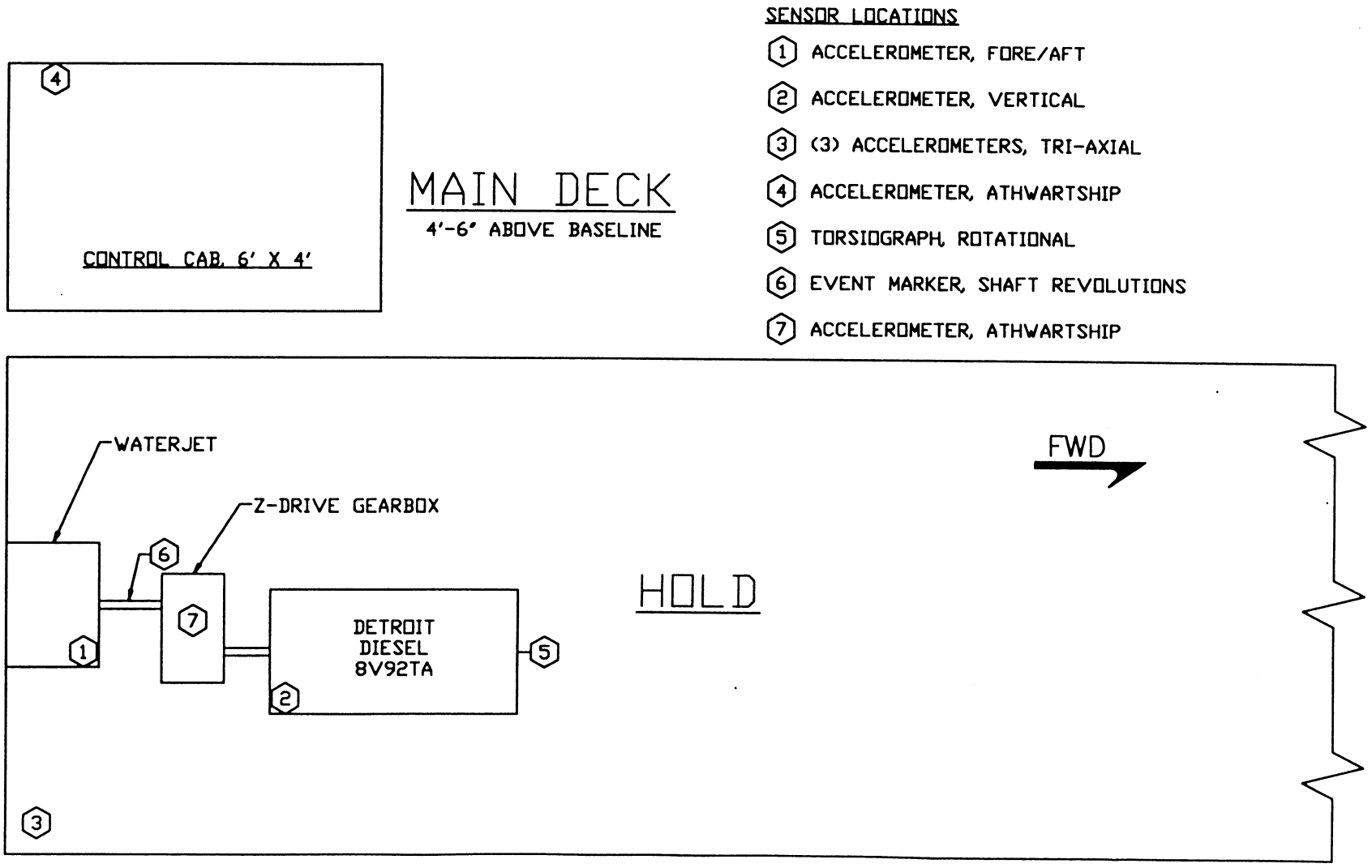

Figure 1. Vibration Sensor Locations

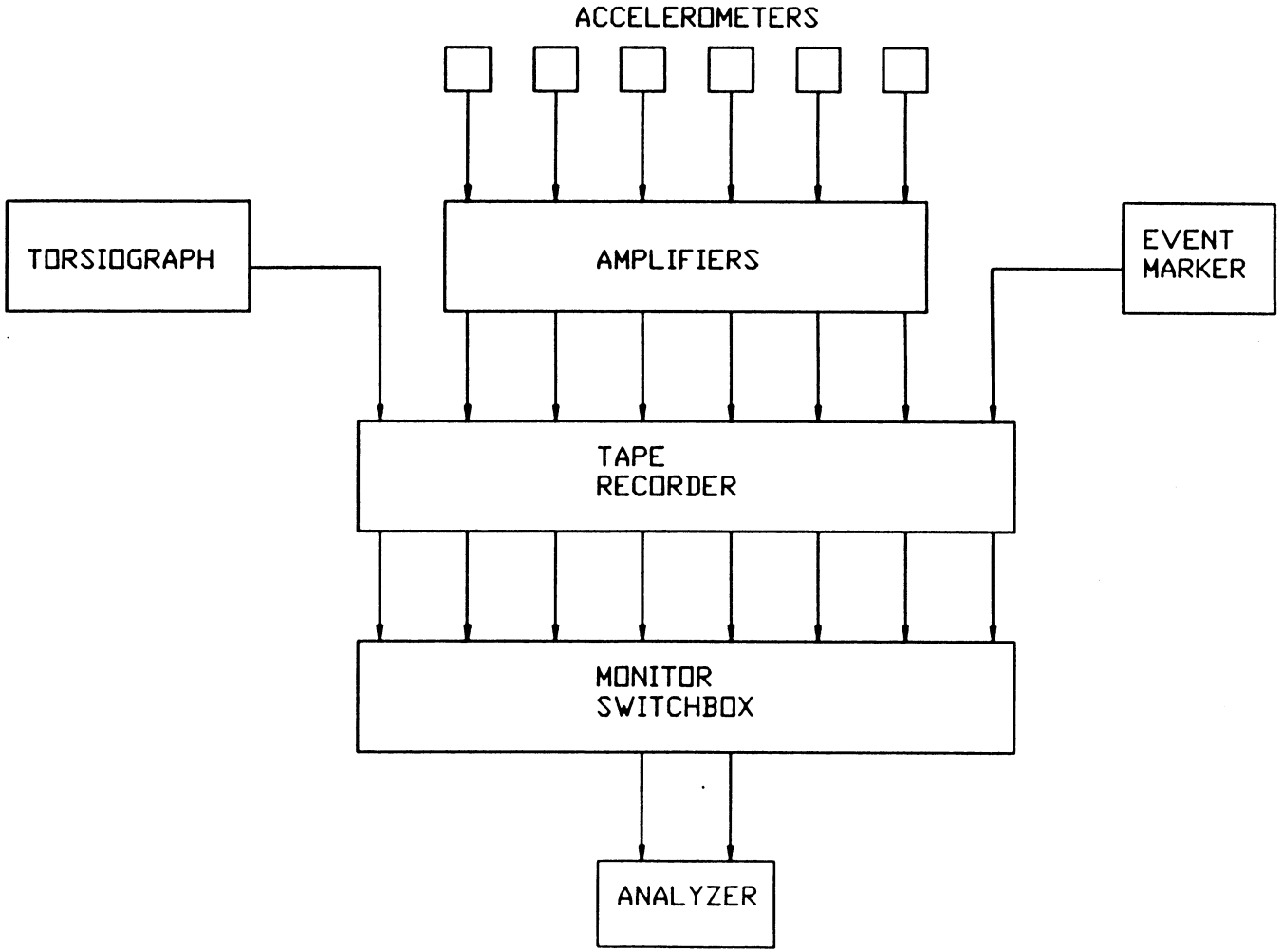

Figure 2. Instrumentation Block Diagram for Data Recording Mode

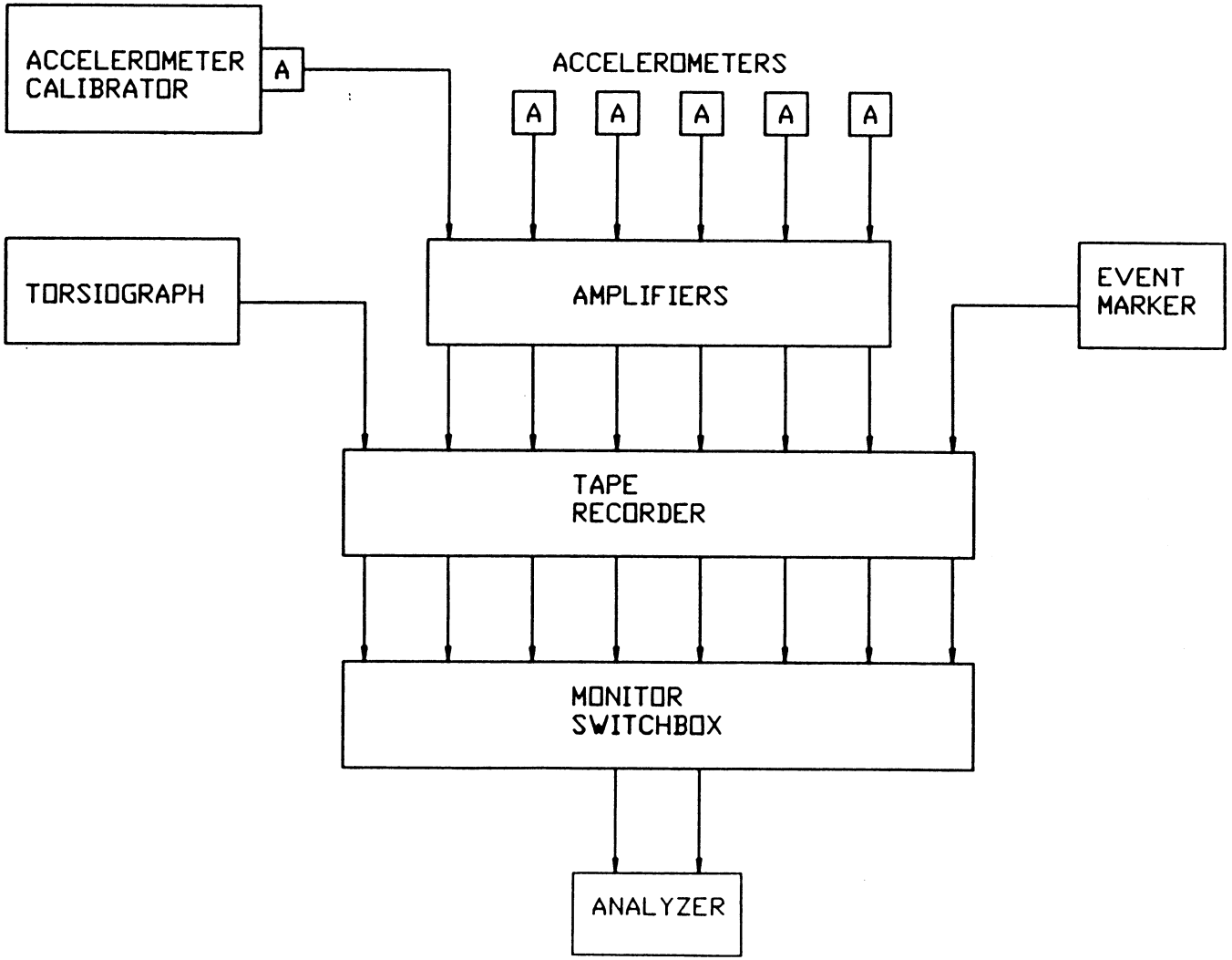

Figure 3. Instrumentation Block Diagram for Accelrometer Calibration Mode

Appendix A

TEST PROCEDURE

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TP-1073-AR-016
CDRL A010

MODULAR CAUSEWAY FERRY VIBRATION MEASUREMENT TEST PROCEDURE

TP-1073-AR-016

CUSTOMER ATCOM

CUSTOMER JOB NO. N/A

CUSTOMER P.O. NO. DAAK01-93-D0007

HULL NOS. First Article

EQUIPMENT Modular Causeway Ferry

EQUIPMENT NO. E03155

EQUIPMENT SERIAL NOS. P40P-0001, P40P-0002 (Powered Modules)

CUSTOMER NOTIFICATION PRIOR TO TESTING 7 DAYS

ENGINEERING NOTIFICATION PRIOR TO TESTING 14 DAYS

LAKE SHORE SALES ORDER NO. 1073AR

DRAWN J. C. Todd DATE Oct 20, 1994

CHECKED R. M. Thompson DATE Oct 21, 1994

APPROVED W. J. Miller DATE Oct 21, 1994

QUALITY Kenneth J. Uusi DATE Oct 21, 1994

LAKE SHORE INC.
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KINGSFORD, MICHIGAN

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Rev	Date	Appvl	QA	Description
—	10/21/94	WJK	LSI 1 QA	Initial Issue
A	1/31/95	WJK	LSI 1 QA	Revised for direction of measurement at measurement locations; Added test for determining resonance.

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VIBRATION MEASUREMENT TEST PROCEDURE

TP-1073-AR-016

1.0 INTRODUCTION

1.1 Objective. The objective of the Vibration Measurement Test is to determine the vibration characteristics of the Propulsion System (including the main engine, reduction gears, thruster, drive shaft, and related equipment) of the Modular Causeway Ferry (MCF) while operating with rated load (350 short tons) at rated speed (6 knots). Testing shall demonstrate that vibration levels of the MCF do not cause severe or damaging vibrations within the Propulsion System or hull as defined by Mil-Std-167-2 for Types III, IV, and V mechanical vibrations.

1.2 Test Item. The test item, described as the MCF, is defined by Lake Shore drawing E03155. The MCF Powered Module is defined by Lake Shore Drawing E02843.

1.3 Test Limitations. Vibration Measurement Testing will be performed in conjunction with Speed Trial Tests, TP-1073-AR-012. Operating conditions are specified in the purchase description as rated load and rated speed. Vibration levels will be measured at intermediate speeds by sweeping through the operating speed range. Measurement locations will be determined by SNAME Codes C-1 and C-4 and through interpretation of Mil-Std-167-2. As specified by Mil-Std-167-2, no testing is required for Type V Lateral Vibration of propulsion shafting.

2.0 REFERENCE DOCUMENTS

2.1	PD 1990-0098	Purchase Description (Para's 4.5.2.7.7, 3.5.8)
2.2	Mil-Std-167-2	Mechanical Vibrations of Shipboard Equipment (Reciprocating Machinery and Propulsion System & Shafting) Types III, IV, & V
2.3	E20001	General Test Requirements
2.4	E20011	Failure Reporting, Analysis, and Corrective Action System (FRACAS)
2.5	SNAME Code C-1	Technical & Research Code, Code for Shipboard Vibration Measurement

2.6	SNAME Code C-4	Technical & Research Code, Code for Local Shipboard Structures and Machinery Vibration Measurements

3.0 TEST PREPARATION

3.1 Approach to Test. The vibration levels of the MCF power train will be determined by measuring and recording the vibration levels in terms of vibration frequency (in Hertz) and vibration amplitude (in inches) and comparing the vibration levels to the forcing function (i.e., the drive train rotational speed) creating the vibration.

Vibration levels will be measured at the hull stern (three axes), and at the machinery foundations of the diesel engine (vertical) and thruster (longitudinal). Vibration levels will be measured at the operator's cab (principle axis). If there is evidence of excessive vibration at any local structure, vibration levels will be measured at that location. Torsional vibration will be measured at the front end of the diesel engine crankshaft.

3.2 General Test Requirements. Refer to the following documents for general test requirements:

E20001	General Test Requirements; location and schedule of test, calibration requirements, safety requirements, and general test documentation.
E20011	Failure Reporting, Analysis, and Corrective Action System (FRACAS).

3.3 Customer Notification. The ATCOM and Government Quality Assurance Representative shall be provided with seven (7) days notification prior to the start of testing.

3.4 Personnel Requirements. The following personnel are required for performance of the Vibration Measurement Test:

3.4.1 Contractor furnished personnel: Test supervisor, MCF operators, MCF crew, test equipment technicians.

3.4.2 Government furnished personnel: Dock side personnel for mooring, fueling, and rigging and handling the MCF load.

3.5 Facilities and Test Equipment. The following facilities, support equipment, and test equipment are required for performance of the Vibration Measurement Test (CFE = Contractor furnished equipment, GFE = Government/Customer furnished equipment):

	CFE	GFE
3.5.1 One (1) complete MCF, outfitted for duty:	X	
3.5.2 A measured course of known distance:	X	
3.5.3 Vibration measurement instrumentation including accelerometers, velocity transducers, integrators, amplifiers, tape recorder, oscillograph, and/or vibration analyzer.	X	
3.5.4 350 short tons of load with rigging for handling the load:		X
3.5.5 Diesel fuel oil, ASTM D975 Grade 2-D or equal:		X
3.5.6 Mooring lines and dockside equipment for mooring the MCF to the pier:		X

3.6 The instrumentation for measuring vibration levels shall be installed to the MCF Powered Module and Operator's Cab at locations indicated in ¶ 4.4.

4.0 TEST PROCEDURE

4.1 Vibration Measurement Testing will be performed in conjunction with the Speed Trial Tests, TP-1073-AR-012. Vibration levels will be measured as the MCF traverses the measured course at full load and full speed. Test documentation shall be recorded on the Test Report TR-1073-AR-016. Unless otherwise defined, testing and test documentation shall be in accordance with SNAME Codes C-1 and C-4.

4.2 Identify all instrumentation used to measure vibration levels (including make, model, serial number) and the calibration procedures and data for the instrumentation.

4.3 Test conditions shall meet the following restrictions.

4.3.1 The test shall be conducted in not less that 20 feet of water.

4.3.2 The test shall be conducted in a quiet sea (Sea State 2 or less).

4.3.3 The test shall determine any resonances of the system by operating the diesel engine through a sweep of the full operating speed range of the engine. If any resonances are found, vibration data shall be taken at the offending engine speed.

4.3.4 The test shall be conducted with the MCF loaded with 350 short tons of cargo and operating at 6 knots.

4.3.5 The test shall be conducted with the MCF being steered in a straight ahead direction with minimum steering action during testing. As test conditions allow, testing may also include vibrations measurements under hard turn conditions.

4.4 Measure and record the vibration data (amplitude of vibration, frequency of vibration, diesel engine speed) for each location identified.

4.4.1 Hull stern location: longitudinal, vertical, athwartship.

4.4.2 Diesel engine foundation: vertical.

4.4.3 Thruster foundation: longitudinal.

4.4.4 Operator's Cab location: Principle axis of vibration.

4.4.5 Local Structure location (identified as having excessive vibration): longitudinal, vertical, athwartship. Identify location of local structure and direction of vibration.

4.4.6 Diesel engine crankshaft: torsional, event marker.

5.0 Acceptance Criteria

5.1 Testing shall demonstrate that vibration levels of the MCF do not cause severe or damaging vibrations within the Propulsion System or hull as defined by Mil-Std-167-2 for Types III, IV, and V mechanical vibrations.

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VIBRATION MEASUREMENT TEST

TEST REPORT

TR-1073-AR-016

CUSTOMER ATCOM

CUSTOMER P.O. NO. DAAK01-93-D-0007

EQUIPMENT MODULAR CAUSEWAY FERRY

POWERED MODULE SERIAL NO. _____

SHOP ORDER _____

TEST COMPLETION DATE _____

Instrumentation and Calibration Data _____

_____

_____

_____

Vibration Measurement Data

Test Data Sheets Attached _____ Acceptable _____ Not Acceptable _____
Accept no excessive or damaging vibration.

Test Witnessed by:

LSI Rep _____ Customer Rep _____ Other _____

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Vibration Measurements:

MODULAR CAUSEWAY FERRY VIBRATION TEST DATA RECORDING SHEET			SEA STATE / DEPTH				DRAFT / DISPL			
TEST CONDUCTOR: ___ DATE: ___			RUN: ___ BEG: ___ END: ___		RUN: ___ BEG: ___ END: ___		RUN: ___ BEG: ___ END: ___		RUN: ___ BEG: ___ END: ___	
	OPERATING CONDITION									
	TAPE CHAN	AMP CHAN	TAPE FS	AMP GAIN	TAPE FS	AMP GAIN	TAPE FS	AMP GAIN	TAPE FS	AMP GAIN
Waterjet F/A	1	1								
Engine Vert	2	2								
Hull F/A	3	3								
Hull Athw	4	4								
Hull Vert	5	5								
Ctrl Cab *	6	6								
Torsiograph	7	N/A								
Rev Marker	8	N/A								
TEST WITNESSED BY:									SHEET NO.	
LSI REP.					CUSTOMER REP.					
COMMENTS:										

Use additional sheets as necessary

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Vibration Measurements:

MODULAR CAUSEWAY FERRY VIBRATION TEST DATA RECORDING SHEET			SEA STATE / DEPTH				DRAFT / DISPL			
TEST CONDUCTOR: ___ DATE: ___			RUN: ___ BEG: ___ END: ___		RUN: ___ BEG: ___ END: ___		RUN: ___ BEG: ___ END: ___		RUN: ___ BEG: ___ END: ___	
	OPERATING CONDITION									
	TAPE CHAN	AMP CHAN	TAPE FS	AMP GAIN	TAPE FS	AMP GAIN	TAPE FS	AMP GAIN	TAPE FS	AMP GAIN
Waterjet F/A	1	1								
Engine Vert	2	2								
Hull F/A	3	3								
Hull Athw	4	4								
Hull Vert	5	5								
Ctrl Cab *	6	6								
Torsiograph	7	N/A								
Rev Marker	8	N/A								

TEST WITNESSED BY:	SHEET NO.
LSI REP.	CUSTOMER REP.

COMMENTS:

Use additional sheets as necessary

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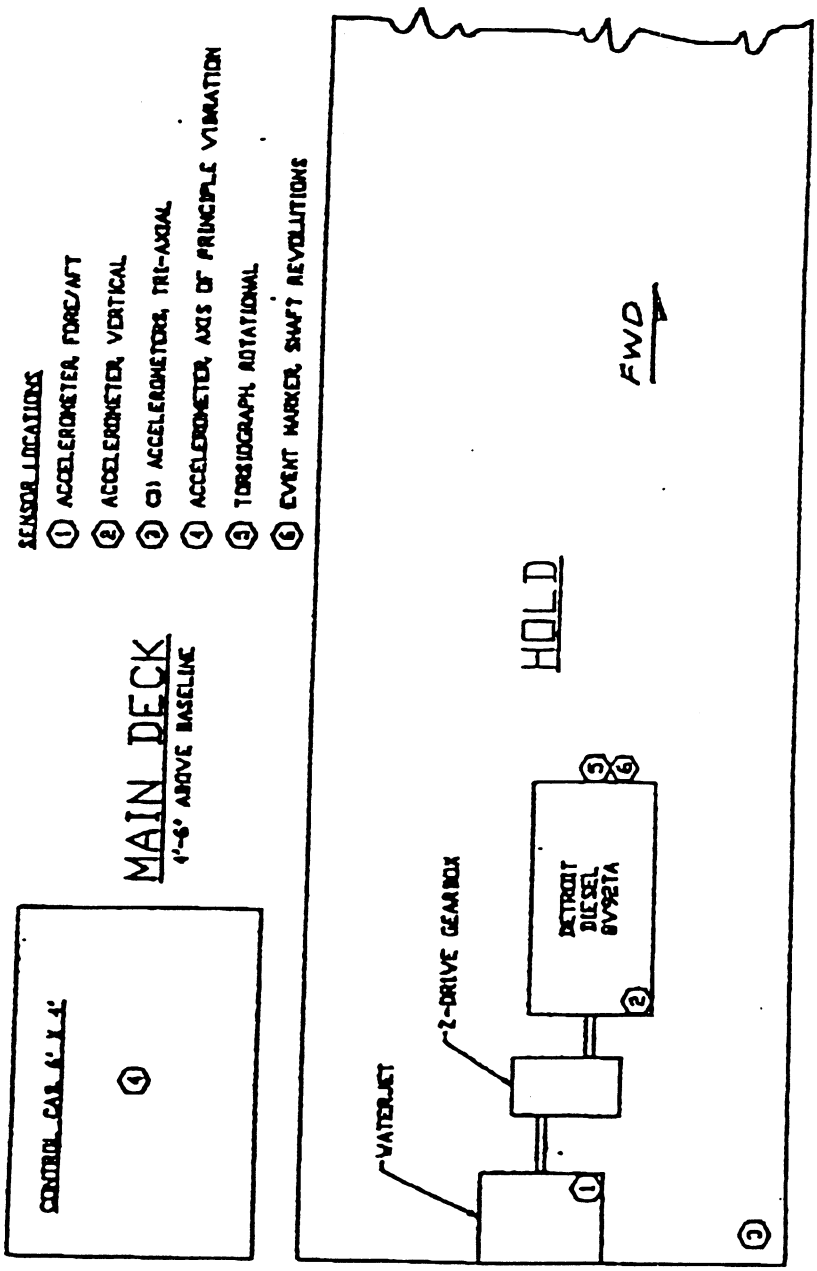

Figure 1. Vibration Sensor Location

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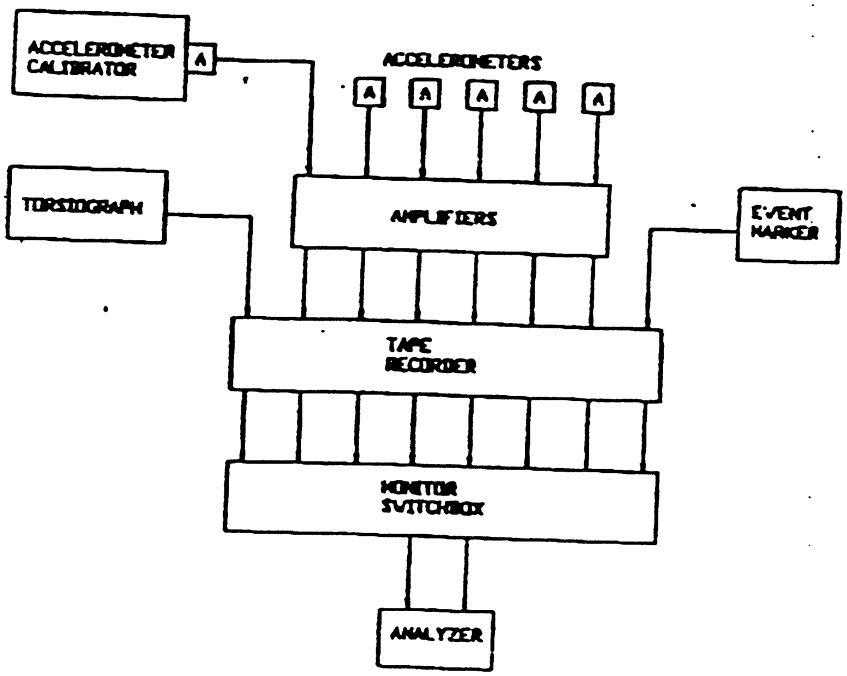


Figure 2. Instrumentation Block Diagram for Accelerometer Calibration Mode

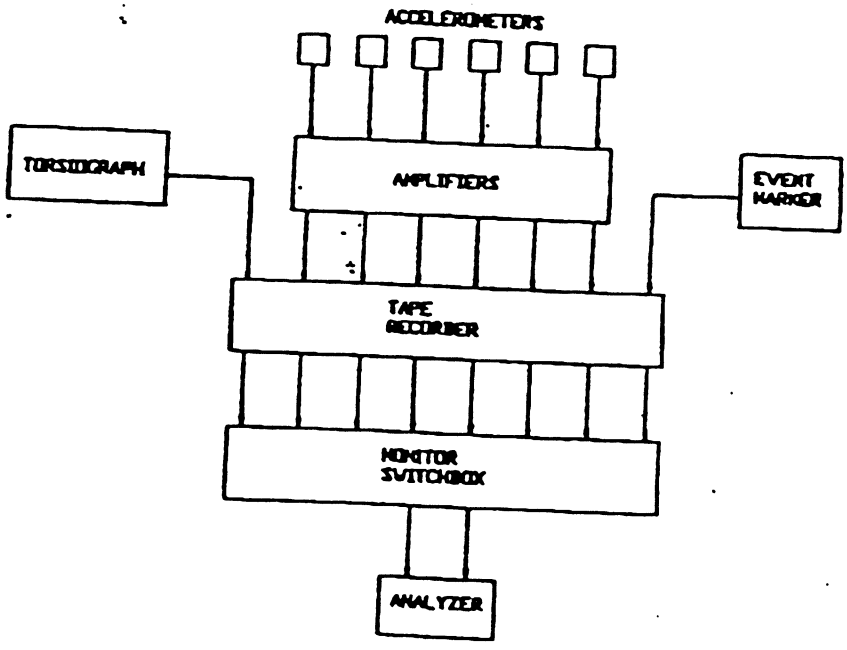


Figure 3. Instrumentation Block Diagram for Data Recording Mode

TAPE SPEED 2.4 cm/sec

MODULAR CAUSEWAY FERRY TEST DATA RECORDING SHEET			SEA STATE 0 DEPTH 20 +		DRAFT 30" DISPL ~~558~~ LONG TONS (558)					
Test Conductor: R. COBB Date: 5/9/95			Run: 1 Beg: 0 End: 10		Run: 2 Beg: 10 End: 20		Run: 3 Beg: 20 End: 30		Run: 4 Beg: 30 End: 40		Run: 5 Beg: 40 End: 50	
	Operating Conditions		CAL		CAL		CAL		CAL		CAL	
	Tape Chan	Amp Chan	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain
Waterjet F/A	#263 1	1	0.2	1.0								
Engine Vert	#274 2	2			0.2	1.0						
Hull F/A	#275 3	3				~~1.0~~	0.2	1.0				
Hull Athw	#276 4	4							0.2	1.0		
Hull Vert	#277 5	5									0.2	1.0
Ctrl Cab •	#175176	6										
Torslograph	7	n/a										
Rev Marker	8	n/a										
ROVING ACC.	#262											

Test Conductor: R. COBB Date: 5/9/95 & 5/11/95			Run: 6 Beg: 50 End: 60		Run: 7 Beg: 60 End: 70		Run: 8 Beg: 100 End: 150		Run: 9 Beg: 250 End: 265		Run: 10 Beg: 265 End: 300	
	Operating Conditions		CAL		CAL		FULL POWER		SPEED SWEEP		775 RPM	
	Tape Chan	Amp Chan	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain
Waterjet F/A	1	1			~~0.2~~		0.2	1.0				
Engine Vert	2	2			6		0.5	1.0				
Hull F/A	3	3					0.2	2.0				
Hull Athw	4	4					0.2	2.0				
Hull Vert	5	5					0.2	2.0			N/C	
Ctrl Cab •	(ATH) 6	6	0.2	1.0			0.2	2.0				
Torslograph	7	n/a					1.0	—				
Rev Marker	8	n/a					1.0	—				
ROVING ACC.	9	7			0.2	1.0	0.2	1.0				
							↑ TOP OF WATER					
							PUMP (ATHW)					

Test Witnessed by: W. T. Kelley — Sheet No. 1

LSI Rep. — Customer Rep.

Comments:

Figure 4. Test Data Recording Sheet

2.4 cm/sec

MODULAR CAUSEWAY FERRY TEST DATA RECORDING SHEET			SEA STATE DEPTH				DRAFT DISPL			
Test Conductor: R. COBB			Run: 11 Beg: 300 End: 333	Run: 12 Beg: 333 End: 367		Run: 13 Beg: 367 End: 400		Run: 14 Beg: 400 End: 435		Run: 15 Beg: 435 End: 468	
Date: 5/11/95											
	Operating Conditions		850	925		1,000		1,075		1150	
	Tape Chan	Amp Chan	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain
Waterjet F/A	1	1	0.2	1.0								
Engine Vert	2	2	0.5	1.0								
Hull F/A	3	3	0.2	2.0				N/C				
Hull Athw	4	4	0.2	2.0								
Hull Vert	5	5	0.2	2.0								
Ctrl Cab • (ATH)	6	6	0.2	2.0								
Torslograph	7	n/a	1.0	~~1.0~~								
Rev Marker	8	n/a	1.0	—								
WATER PUMP TOP (ATHWART)	9	7	0.2	1.0								

Test Conductor: R. COBB			Run: 16 Beg: 468 End: 500	Run: 17 Beg: 500 End: 533		Run: 18 Beg: 533 End: 567		Run: 19 Beg: 567 End: 600		Run: 20 Beg: 600 End: 633	
Date: 5/11/95											
	Operating Conditions		1225	1300		1375		1450		1525	
	Tape Chan	Amp Chan	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain
Waterjet F/A	1	1	0.2	1.0								
Engine Vert	2	2	0.5	1.0								
Hull F/A	3	3	0.2	2.0								
Hull Athw	4	4	0.2	2.0				N/C				
Hull Vert	5	5	0.2	2.0								
Ctrl Cab • (ATH)	6	6	0.2	2.0								
Torslograph	7	n/a	1.0	—								
Rev Marker	8	n/a	1.0	—								
WATER PUMP (TOP) (ATHWART SHIP)	9	7	0.2	1.0								

Test Witnessed by: Sheet No. 2

LSI Rep. Customer Rep.

Comments:

Figure 4. Test Data Recording Sheet

2.4 cm/sec

MODULAR CAUSEWAY FERRY TEST DATA RECORDING SHEET			SEA STATE DEPTH				DRAFT DISPL			
Test Conductor: R. COBB		Run: 21 Beg: 633	Run: 22 Beg: 667		Run: 23 Beg: 700		Run: 24 Beg: 733		Run: 25 Beg: 767	
Date: 5/11/95		End: 667	End: 700		End: 733		End: 767		End: 800	
	Operating Conditions	(1600) 1575	1675		1750		1825		1900	
	Tape Chan / Amp Chan	Tape FS / Amp Gain	Tape FS / Amp Gain		Tape FS / Amp Gain		Tape FS / Amp Gain		Tape FS / Amp Gain	
Waterjet F/A	1 / 1	0.2 / 1.0								
Engine Vert	2 / 2	0.5 / 1.0								
Hull F/A	3 / 3	0.2 / 2.0								
Hull Athw	4 / 4	0.2 / 2.0								
Hull Vert	5 / 5	0.2 / 2.0								
Ctrl Cab •	6 / 6	0.2 / 2.0		N/C						
Torsiograph	7 / n/a	1.0 / —								
Rev Marker	8 / n/a	1.0 / —								
WATER PUMP 3rd (ATHW)	9 / 7	0.2 / 1.0								

Test Conductor: R. COBB		Run: 26 Beg: 800	Run: 27 Beg: 833		Run: 28 Beg: 867		Run: 29 Beg: 900		Run: 30 Beg: 933	
Date: 5/11/95		End: 833	End: 867		End: 900		End: 933		End: 968	
	Operating Conditions	1975	2050		2100		2175		PULL STOPPED (2250?)	
	Tape Chan / Amp Chan	Tape FS / Amp Gain	Tape FS / Amp Gain		Tape FS / Amp Gain		Tape FS / Amp Gain		Tape FS / Amp Gain	
Waterjet F/A	1 / 1	0.2 / 1.0								
Engine Vert	2 / 2	0.5 / 1.0								
Hull F/A	3 / 3	0.2 / 2.0								
Hull Athw	4 / 4	0.2 / 2.0								
Hull Vert	5 / 5	0.2 / 2.0				N/C				
Ctrl Cab •	6 / 6	0.2 / 2.0								
Torsiograph	7 / n/a	1.0 / —								
Rev Marker	8 / n/a	1.0 / —								
	9 / 7	0.2 / 1.0								

Test Witnessed by: Sheet No. 3

LSI Rep. Customer Rep.

Comments:

Figure 4. Test Data Recording Sheet

MODULAR CAUSEWAY FERRY TEST DATA RECORDING SHEET			SEA STATE 0 DEPTH not				DRAFT 30'11 DISPL ~~450~~ LONG TONS/558			
Test Conductor: K. COBB Date: 5/11/95		Run: 31 Beg: 968 End: 1060	Run: 32 Beg: 1060 End: 1127		Run: 33 Beg: 1127 End: 1210		Run: _____ Beg: _____ End: _____		Run: _____ Beg: _____ End: _____	
	Operating Conditions	CRASH ASTERN	CRASH ASTERN		LEFT 360° TURN					
	Tape Chan	Amp Chan	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain
Waterjet F/A	1	1	0.5	1.0								
Engine Vert	2	2	1.0	1.0								
Hull F/A	3	3	0.5	2.0								
Hull Athw	4	4	0.5	2.0			N/C					
Hull Vert	5	5	0.5	2.0			→					
Ctrl Cab *	6	6	0.5	2.0								
Torslograph	7	n/a	1.4	—								
Rev Marker	8	n/a	1.0	—								
WATER PUMP TOP (ATHW)	9	7	0.5	1.0								

Test Conductor: Date:		Run: _____ Beg: _____ End: _____	Run: _____ Beg: _____ End: _____		Run: _____ Beg: _____ End: _____		Run: _____ Beg: _____ End: _____		Run: _____ Beg: _____ End: _____	
	Operating Conditions									
	Tape Chan	Amp Chan	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain	Tape FS	Amp Gain
Waterjet F/A	1	1		1.0								
Engine Vert	2	2		1.0								
Hull F/A	3	3		2.0								
Hull Athw	4	4		2.0								
Hull Vert	5	5		2.0								
Ctrl Cab *	6	6		2.0								
Torslograph	7	n/a		—								
Rev Marker	8	n/a		—								
	9	7		1.0								

Test Witnessed by:	Sheet No. 4
LSI Rep.	Customer Rep.
Comments:	

Figure 4. Test Data Recording Sheet

Appendix B

CALIBRATION DATA

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

ACCELEROMETER

Manufactured By: WILCOXON RESEARCH
Model No: M766 Serial No: 262
Calibration Recall No: 1959

Submitted by:

Customer: BOB GUTHRIE
Company: NKF ENGINEERING INC.

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Specification No. M766 WR (see attached)

Upon receipt for Calibration, the instrument was found to be:

Within (X)
Outside ( ) see attached data

the tolerance of the indicated specification.

West Caldwell Calibration Laboratories' calibration control system meets the requirements of MIL-STD-45662A

Approved by:

Calibration Date: January 12, 1995
Certificate No: 1959 -16
Calibration Due: January 12, 1996

Felix A.Christopher

uncompromised calibration
West Caldwell Calibration Laboratories, Inc.

1086 Bloomfield Avenue
West Caldwell
New Jersey
07006

Telephone
(201) 882-4900
Fax
(201) 808-9297

West Caldwell Calibration Laboratories Inc.

1086 Bloomfield Ave. West Caldwell NJ 07006

Accelerometer Voltage Sensitivity (Sv)

Report no: 1959 -16

Control no: 1959 Customer: **NKF Engineering Inc.**

Temp. 22 °C RH: 27%

Barometric Pressure: 760 mm Hg

The listed instrument was checked on B&K 9610 system using work unit code listed below. Revision 2/92

Felix A. Christopher

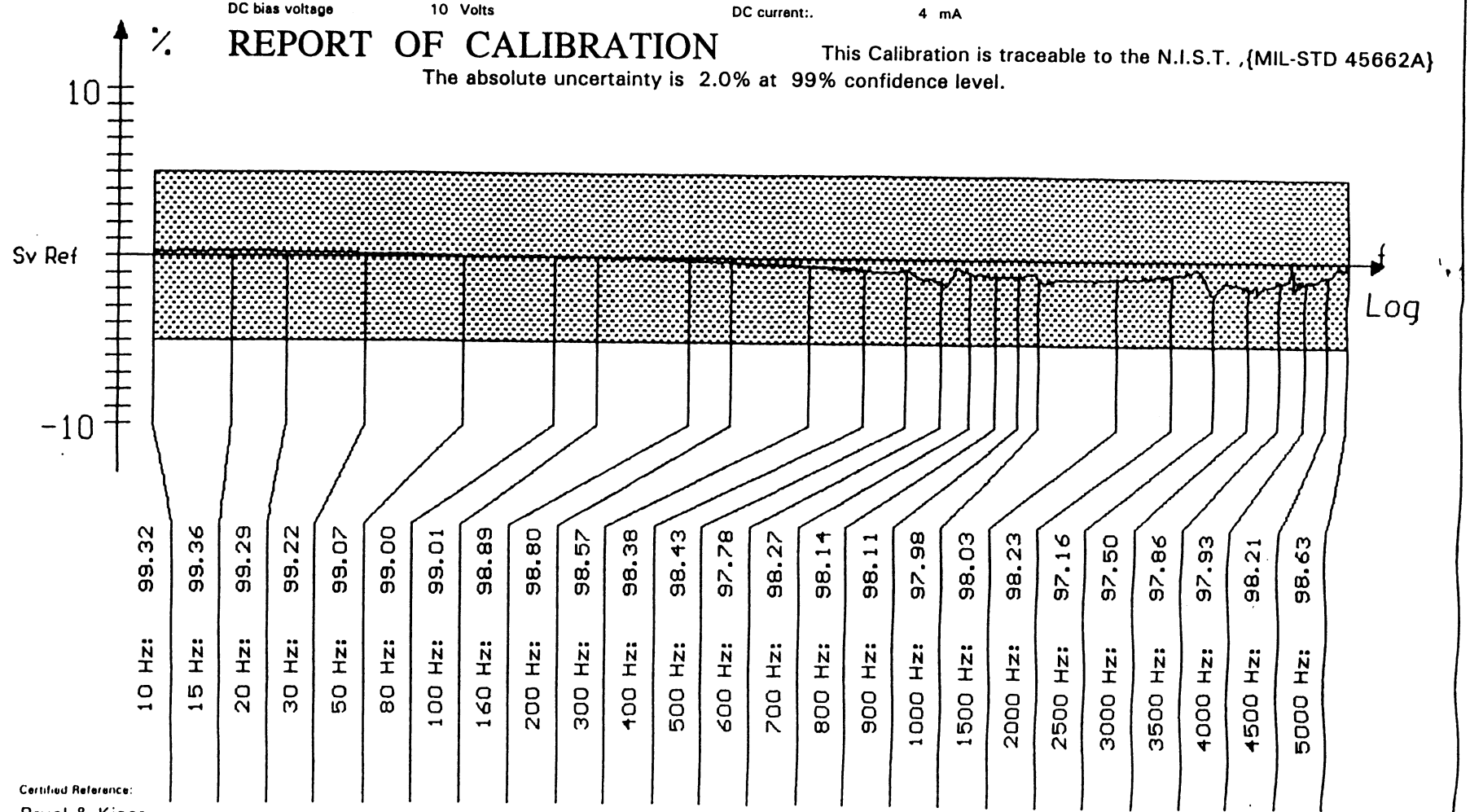
Manufacturer	: Wilcoxon Resea.	Work Unit Code	: M766WR	Operator ID	: CHRIS
Part No.	: M766	Measurement Angle	: 0 °	Calibration Date	: 12 Jan 1995, 12:12
Serial No.	: 262	Ref. Sensitivity	: Passed	Last Cal. Date	: 18 May 1994, 10:25
Freq. range	: 10-5000 Hz	Generator range	: As freq. range		

DC bias voltage 10 Volts DC current:. 4 mA

REPORT OF CALIBRATION

This Calibration is traceable to the N.I.S.T. ,{MIL-STD 45662A}

The absolute uncertainty is 2.0% at 99% confidence level.



Certified Reference:
Bruel & Kjaer
8305
S/N 1777437

Ref. Sensitivity @ 100Hz: 99.01 mV/g

Date of Cal. July 18,94 Due Date July 18,95 NIST Test No. 822/253333-94

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

ACCELEROMETER

Manufactured By: WILCOXON RESEARCH
Model No: M766 Serial No: 263
Calibration Recall No: 1959

Submitted by:

Customer: BOB GUTHRIE
Company: NKF ENGINEERING INC.

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Specification No. M766 WR (see attached)

Upon receipt for Calibration, the instrument was found to be:

Within (X)
Outside ( ) see attached data

the tolerance of the indicated specification.

West Caldwell Calibration Laboratories' calibration control system meets the requirements of MIL-STD-45662A

Approved by:

Calibration Date: January 12, 1995
Certificate No: 1959 -17
Calibration Due: January 12, 1996

Felix A.Christopher

West Caldwell Calibration Laboratories, Inc.
uncompromised calibration

1086 Bloomfield Avenue
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(201) 882-4900
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(201) 808-9297

West Caldwell Calibration Laboratories Inc.

1086 Bloomfield Ave. West Caldwell NJ 07006

Accelerometer Voltage Sensitivity (Sv)

Report no: 1959 -17

Control no: 1959 Customer: **NKF Engineering Inc.**

Temp. 22 °C RH: 27%

The listed instrument was checked on B&K 9610 system using work unit code listed below. Revision 2/92

Barometric Pressure: 760 mm Hg

Felix A. Christopher

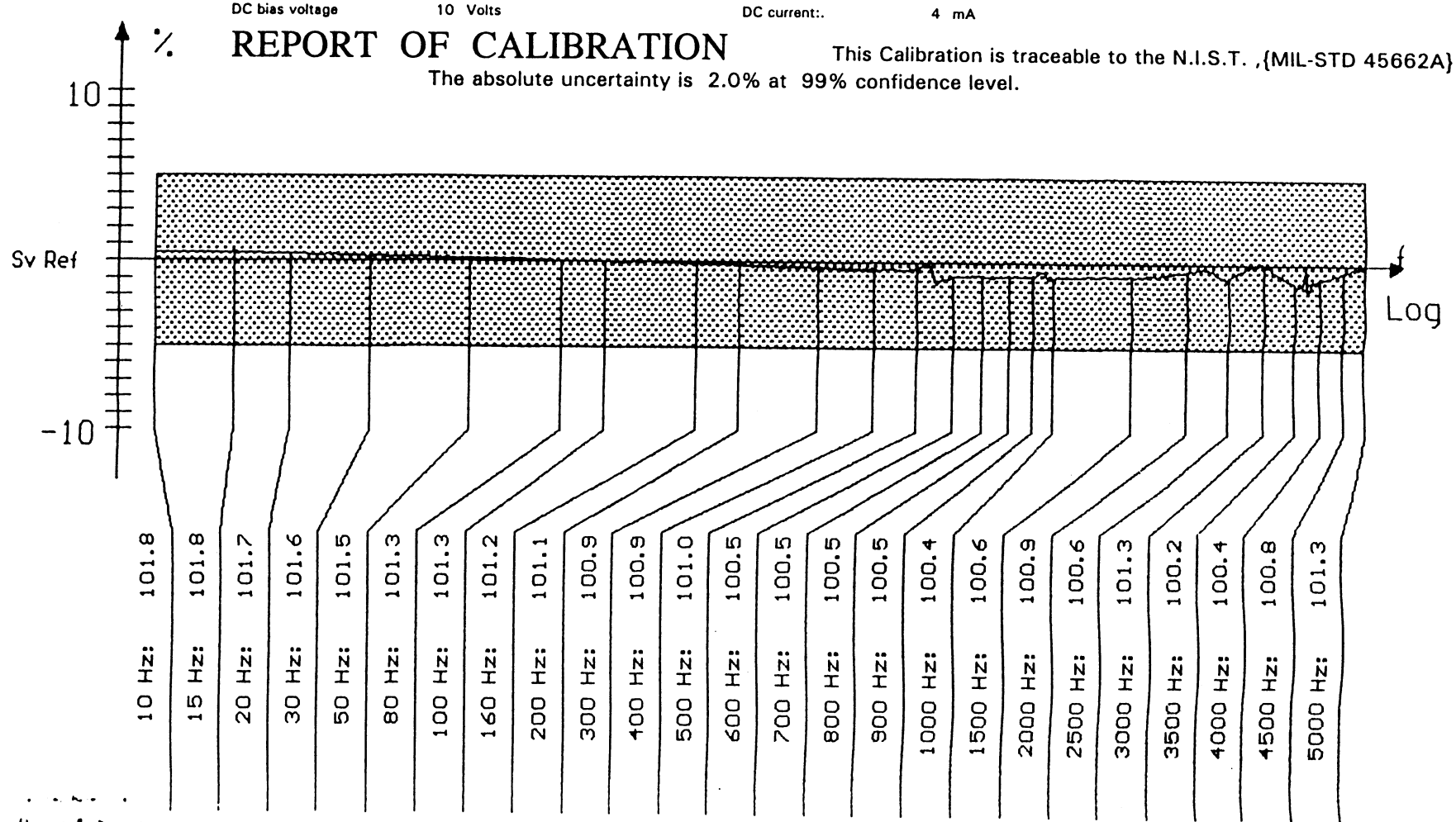
Manufacturer	: Wilcoxon Resea.	Work Unit Code	: M766WR	Operator ID	: CHRIS
Part No.	: M766	Measurement Angle	: 0 °	Calibration Date	: 12 Jan 1995, 12:17
Serial No.	: 263	Ref. Sensitivity	: Passed	Last Cal. Date	: 18 May 1994, 10:37
Freq. range	: 10-5000 Hz	Generator range	: As freq. range		

DC bias voltage 10 Volts DC current:. 4 mA

REPORT OF CALIBRATION

This Calibration is traceable to the N.I.S.T. ,{MIL-STD 45662A}

The absolute uncertainty is 2.0% at 99% confidence level.



Brüel & Kjær

B &K

S.N. 1777417

Ref. Sensitivity @ 100Hz: 101.3 mV/g

Date of Cal: July 18,94 Due Date July 18,95 NIST Test No. 822/253333-94

Calibrated on Brüel & Kjær system

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

ACCELEROMETER

Manufactured By: WILCOXON RESEARCH
Model No: M766 Serial No: 274
Calibration Recall No: 1959

Submitted by:

Customer: BOB GUTHRIE
Company: NKF ENGINEERING INC.

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Specification No. M766 WR (see attached)

Upon receipt for Calibration, the instrument was found to be:

Within (X)
Outside ( ) see attached data

the tolerance of the indicated specification.

West Caldwell Calibration Laboratories' calibration control system meets the requirements of MIL-STD-45662A

Approved by:

Calibration Date: January 12, 1995
Certificate No: 1959 -18
Calibration Due: January 12, 1996

Felix A.Christopher

uncompromised calibration
West Caldwell Calibration Laboratories, Inc.

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(201) 882-4900
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(201) 808-9297

West Caldwell Calibration Laboratories Inc.

1086 Bloomfield Ave. West Caldwell NJ 07006

Accelerometer Voltage Sensitivity (Sv)

Report no: 1959 -18

Control no: 1959 Customer: **NKF Engineering Inc.**

Temp. 22 °C RH: 27%

Barometric Pressure: 760 mm Hg

The listed instrument was checked on B&K 9610 system using work unit code listed below. Revision 2/92

Felix A. Christopher

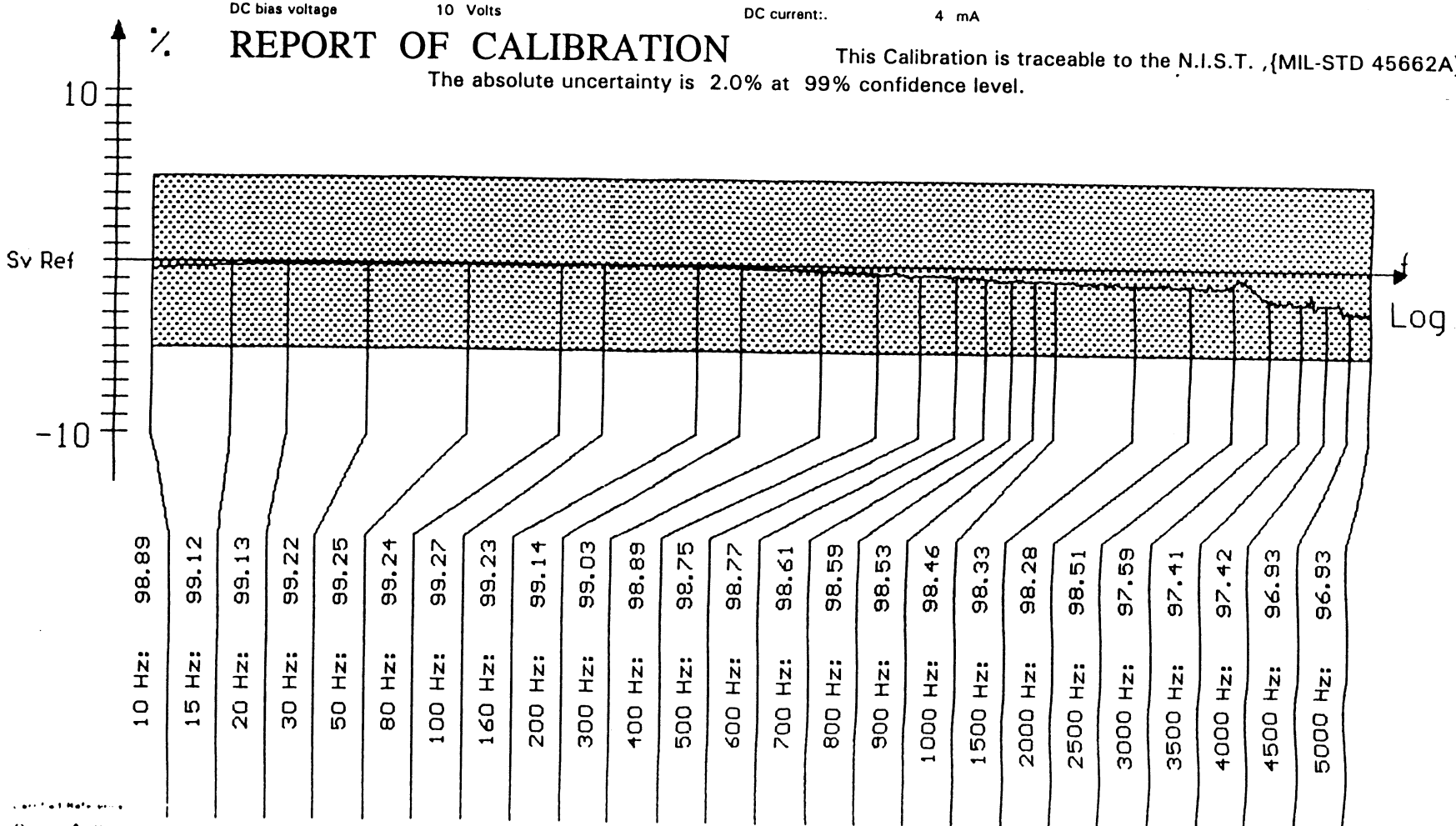
Manufacturer	: Wilcoxon Resea.	Work Unit Code	: M766WR	Operator ID	: CHRIS
Part No.	: M766	Measurement Angle	: 0 °	Calibration Date	: 12 Jan 1995, 12:27
Serial No.	: 274	Ref. Sensitivity	: Passed	Last Cal. Date	: 14 Feb 1994, 18:28
Freq. range	: 10-5000 Hz	Generator range	: As freq. range		

DC bias voltage 10 Volts DC current:. 4 mA

REPORT OF CALIBRATION

This Calibration is traceable to the N.I.S.T. ,{MIL-STD 45662A}

The absolute uncertainty is 2.0% at 99% confidence level.



Brüel & Kjær
8305
S N 1777437

Ref. Sensitivity @ 100Hz: 99.27 mV/g

Date of Cal July 18 94 Due Date July 18,95 NIST Test No. 822/253333-94

K&I Isio POL
Torrance, CA 90503 #PV119E

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

ACCELEROMETER

Manufactured By: WILCOXON RESEARCH
Model No: M766 Serial No: 275
Calibration Recall No: 1959

Submitted by:

Customer: BOB GUTHRIE
Company: NKF ENGINEERING INC.

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Specification No. M766 WR (see attached)

Upon receipt for Calibration, the instrument was found to be:

Within (X)
Outside ( ) see attached data

the tolerance of the indicated specification.

West Caldwell Calibration Laboratories' calibration control system meets the requirements of MIL-STD-45662A.

Approved by:

Calibration Date: January 12, 1995
Certificate No: 1959 -19
Calibration Due: January 12, 1996

Felix A.Christopher

uncompromised calibration West Caldwell Calibration Laboratories, Inc.

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(201) 808-9297

West Caldwell Calibration Laboratories Inc.

1086 Bloomfield Ave. West Caldwell NJ 07006

Accelerometer Voltage Sensitivity (Sv)

Report no: 1959 -19

Control no: 1959 Customer: **NKF Engineering Inc.**

Temp. 22 °C RH: 27%

The listed instrument was checked on B&K 9610 system using work unit code listed below. Revision 2/92

Barometric Pressure: 760 mm Hg

Felix A. Christopher

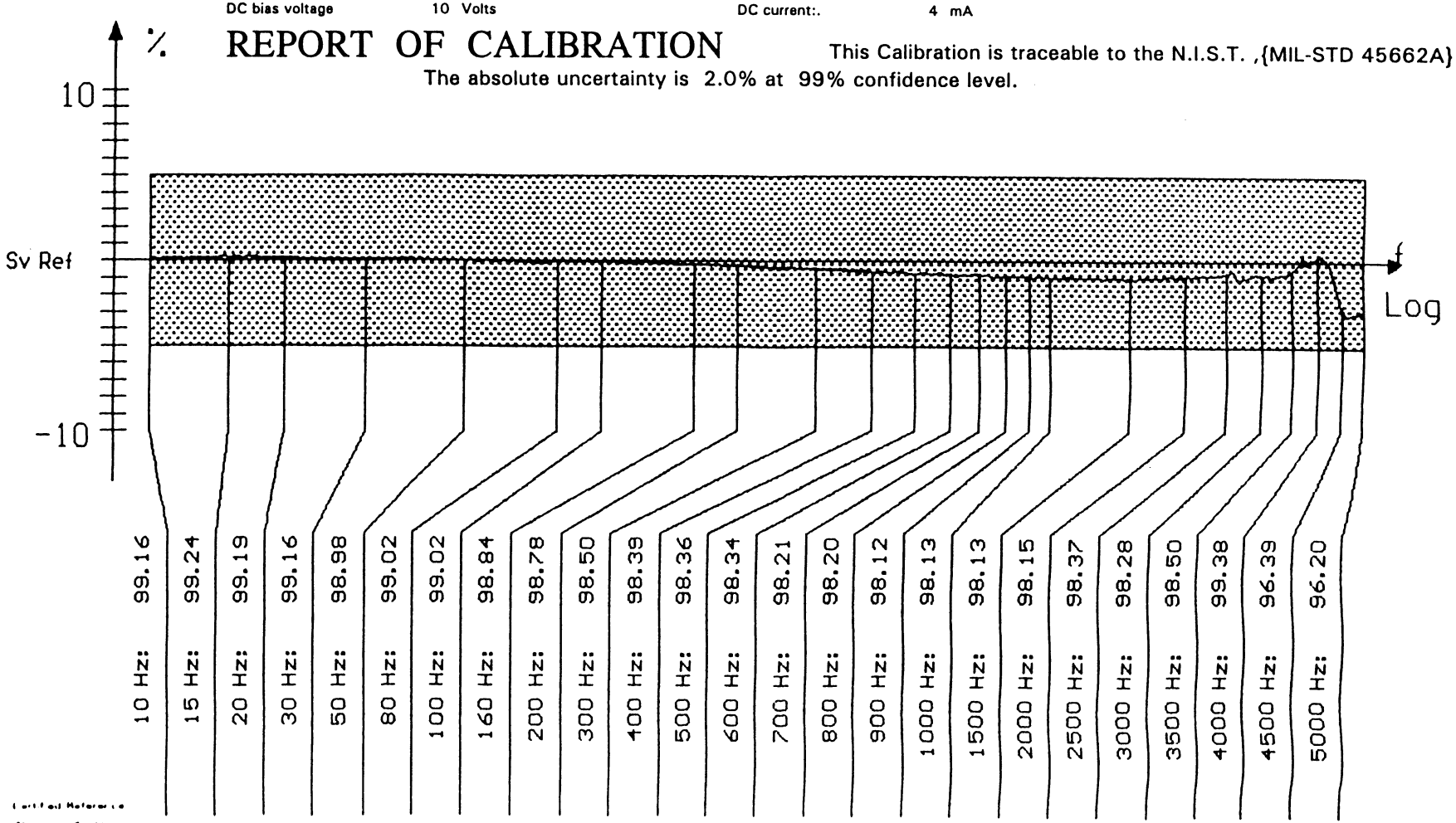
Manufacturer	: Wilcoxon Resea.	Work Unit Code	: M766WR	Operator ID	: CHRIS
Part No.	: M766	Measurement Angle	: 0 D	Calibration Date	: 12 Jan 1995, 12:32
Serial No.	: 275	Ref. Sensitivity	: Passed	Last Cal. Date	: 14 Feb 1994, 18:46
Freq. range	: 10-5000 Hz	Generator range	: As freq. range		

DC bias voltage 10 Volts DC current:. 4 mA

REPORT OF CALIBRATION

This Calibration is traceable to the N.I.S.T. ,{MIL-STD 45662A}

The absolute uncertainty is 2.0% at 99% confidence level.



Brüel & Kjaer
8305
S N 1777437

Ref. Sensitivity @ 100Hz: 99.02 mV/g

Date of Cal July 18,94 Due Date July 18,95 NIST Test No. 822/253333-94

Calibrated on Brüel & Kjaer system 9610

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

ACCELEROMETER

Manufactured By: WILCOXON RESEARCH
Model No: M766 Serial No: 276
Calibration Recall No: 1959

Submitted by:

Customer: BOB GUTHRIE
Company: NKF ENGINEERING INC.

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Specification No. M766 WR (see attached)

Upon receipt for Calibration, the instrument was found to be:

Within (X)
Outside ( ) see attached data

the tolerance of the indicated specification.

West Caldwell Calibration Laboratories' calibration control system meets the requirements of MIL-STD-45662A

Approved by:

Calibration Date: January 12, 1995
Certificate No: 1959 -20
Calibration Due: January 12, 1996

Felix A.Christopher

West Caldwell Calibration Laboratories, Inc.
uncompromised calibration

1086 Bloomfield Avenue
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(201) 808-9297

Vest Caldwell Calibration Laboratories Inc.

1086 Bloomfield Ave. West Caldwell NJ 07006

Accelerometer Voltage Sensitivity (Sv)

Report no: 1959 -20

Control no: 1959 Customer: **NKF Engineering Inc.**

Temp. 22 °C RH: 27%

Barometric Pressure: 760 mm Hg

The listed instrument was checked on B&K 9610 system using work unit code listed below. Revision 2/92

Felix A. Christopher

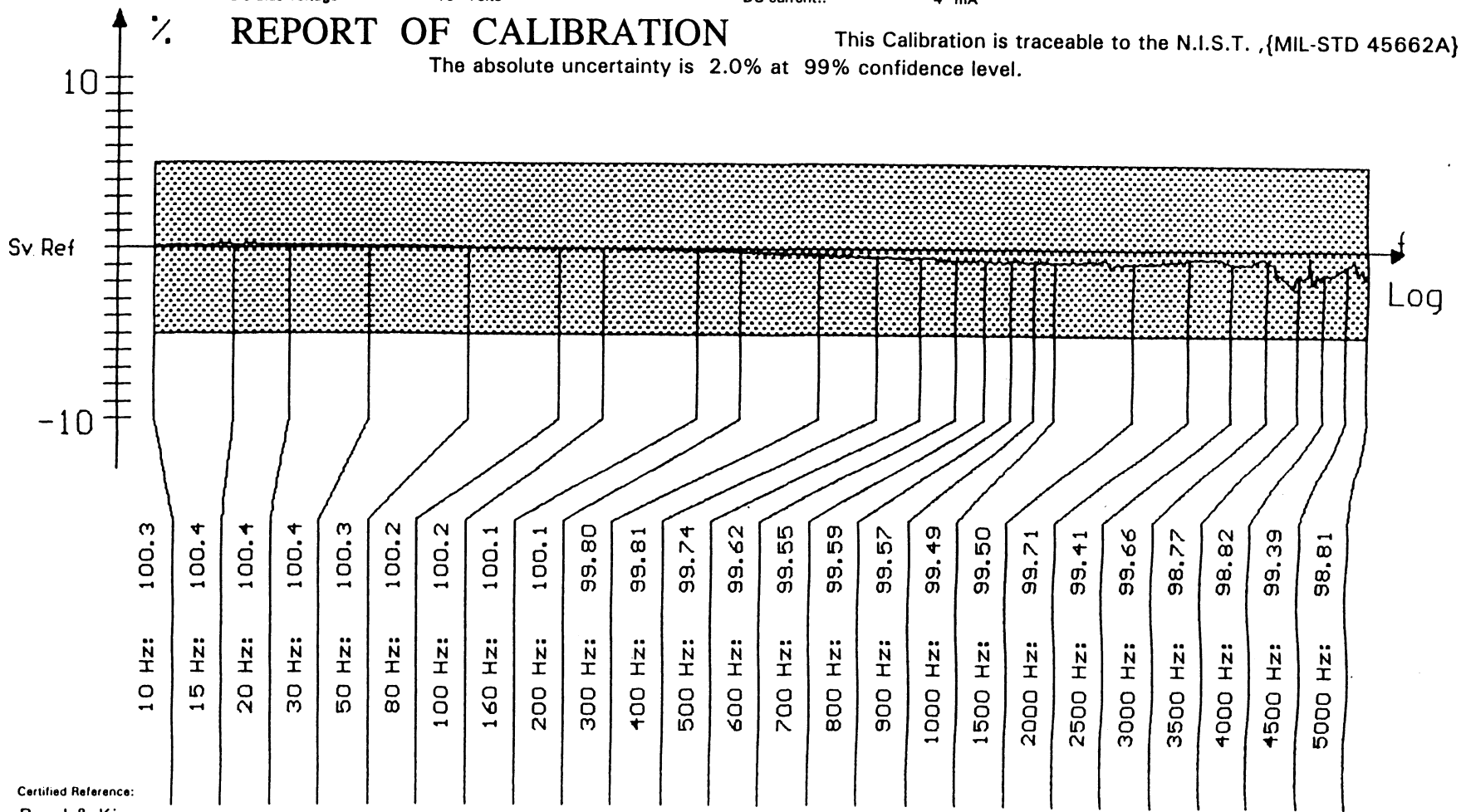
Manufacturer	: Wilcoxon Resea.	Work Unit Code	: M766WR	Operator ID	: CHRIS
Part No.	: M766	Measurement Angle	: 0 °	Calibration Date	: 12 Jan 1995, 12:38
Serial No.	: 276	Ref. Sensitivity	: Passed	Last Cal. Date	: 14 Feb 1994, 18:35
Freq. range	: 10-5000 Hz	Generator range	: As freq. range		

DC bias voltage 10 Volts DC current:. 4 mA

REPORT OF CALIBRATION

This Calibration is traceable to the N.I.S.T. ,{MIL-STD 45662A}

The absolute uncertainty is 2.0% at 99% confidence level.



Certified Reference:
Bruel & Kjaer
8305
S/N 1777437

Ref. Sensitivity @ 100Hz: 100.2 mV/g

Date of Cal. July 18,94 Due Date July 18,95 NIST Test No. 822/253333-94

Calibrated on Brüel & Kjær system type 9610

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

ACCELEROMETER

Manufactured By: WILCOXON RESEARCH
Model No: M766 Serial No: 277
Calibration Recall No: 1959

Submitted by:

Customer: BOB GUTHRIE
Company: NKF ENGINEERING INC.

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Specification No. M766 WR (see attached)

Upon receipt for Calibration, the instrument was found to be:

Within (X)
Outside ( ) see attached data

the tolerance of the indicated specification.

West Caldwell Calibration Laboratories' calibration control system meets the requirements of MIL-STD-45662A

Approved by:

Calibration Date: January 12, 1995
Certificate No: 1959 -21
Calibration Due: January 12, 1996

Felix A.Christopher

uncompromised calibration
West Caldwell Calibration Laboratories, Inc.

1086 Bloomfield Avenue
West Caldwell
New Jersey
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(201) 882-4900
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(201) 808-9297

West Caldwell Calibration Laboratories Inc.

1086 Bloomfield Ave. West Caldwell NJ 07006

Accelerometer Voltage Sensitivity (Sv)

Report no: 1959 -21

Control no: 1959 Customer: **NKF Engineering Inc.**

Temp. 22 °C RH: 27%

Barometric Pressure: 760 mm Hg

The listed instrument was checked on B&K 9610 system using work unit code listed below. Revision 2/92

Felix A. Christopher

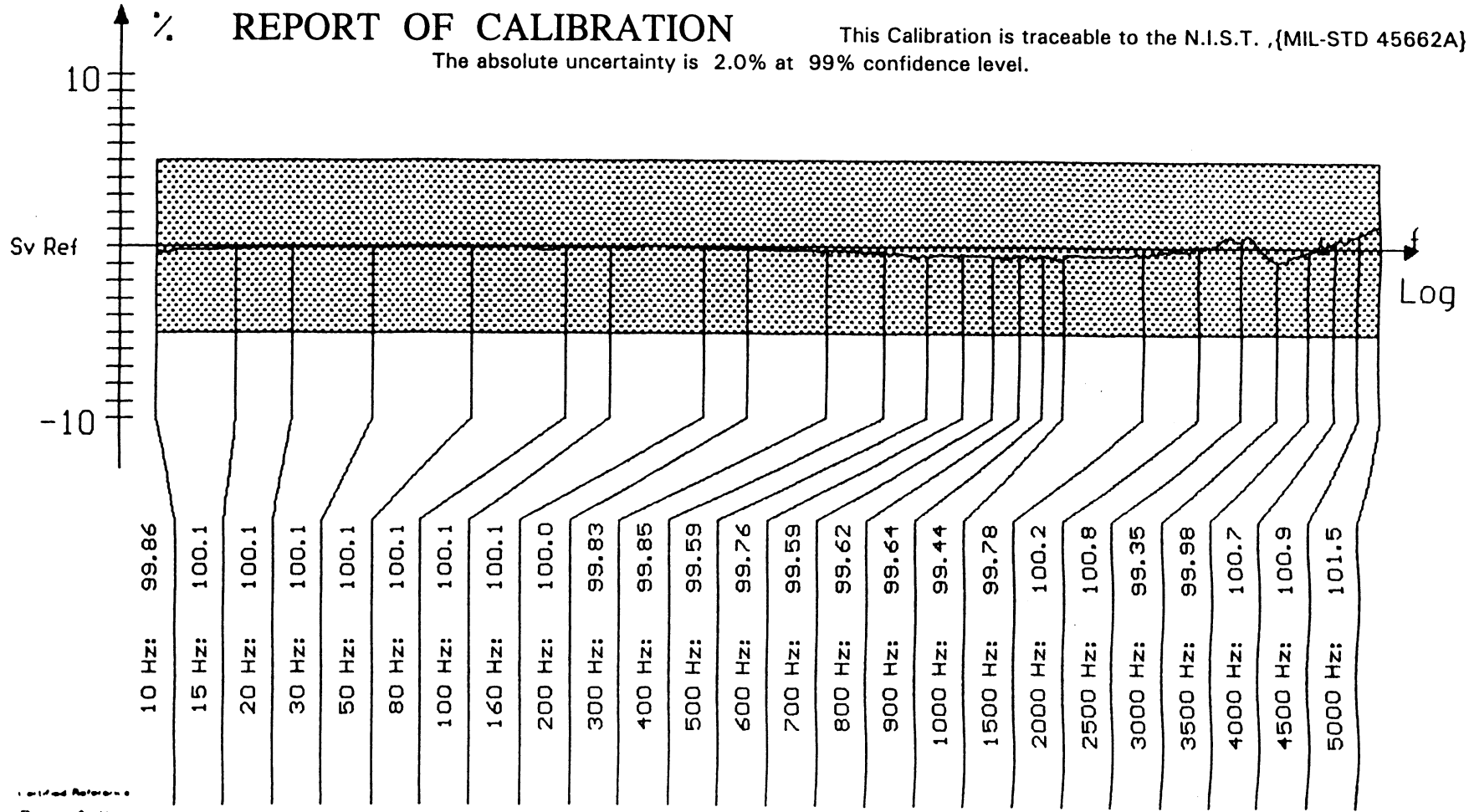
Manufacturer	: Wilcoxon Resea.	Work Unit Code	: M766WR	Operator ID	: CHRIS
Part No.	: M766	Measurement Angle	: 0 °	Calibration Date	: 12 Jan 1995, 12:44
Serial No.	: 277	Ref. Sensitivity	: Passed	Last Cal. Date	: 14 Feb 1994, 18:40
Freq. range	: 10-5000 Hz	Generator range	: As freq. range		

DC bias voltage 10 Volts DC current:. 4 mA

REPORT OF CALIBRATION

This Calibration is traceable to the N.I.S.T. ,{MIL-STD 45662A}

The absolute uncertainty is 2.0% at 99% confidence level.



Brüel & Kjaer
8305
S N 1777437

Ref. Sensitivity @ 100Hz: 100.1 mV/g

Date of Cal July 18,94 Due Date July 18,95 NIST Test No. 822/253333-94

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

ACCELEROMETER

Manufactured By: PCB
Model No: 328A51 Serial No: 17517
Calibration Recall No: 1959

Submitted by:

Customer: BOB GUTHRIE
Company: NKF ENGINEERING INC.

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Specification No. 328A51 PCB (see attached)

Upon receipt for Calibration, the instrument was found to be:

Within (X)
Outside ( ) see attached data

the tolerance of the indicated specification.

West Caldwell Calibration Laboratories' calibration control system meets the requirements of MIL-STD-45662A

Approved by:

Calibration Date: January 12, 1995
Certificate No: 1959 -15
Calibration Due: January 12, 1996

Felix A.Christopher

uncompromised calibration West Caldwell Calibration Laboratories, Inc.

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West Caldwell Calibration Laboratories Inc.

1086 Bloomfield Ave. West Caldwell NJ 07006

Accelerometer Voltage Sensitivity (Sv)

Report no: 1959 -15

Control no: 1959 Customer: **NKF Engineering Inc.**

Temp. 22 °C RH: 27%

Barometric Pressure: 760 mm Hg

The listed instrument was checked on B&K 9610 system using work unit code listed below. Revision 2/92

Felix A. Christopher

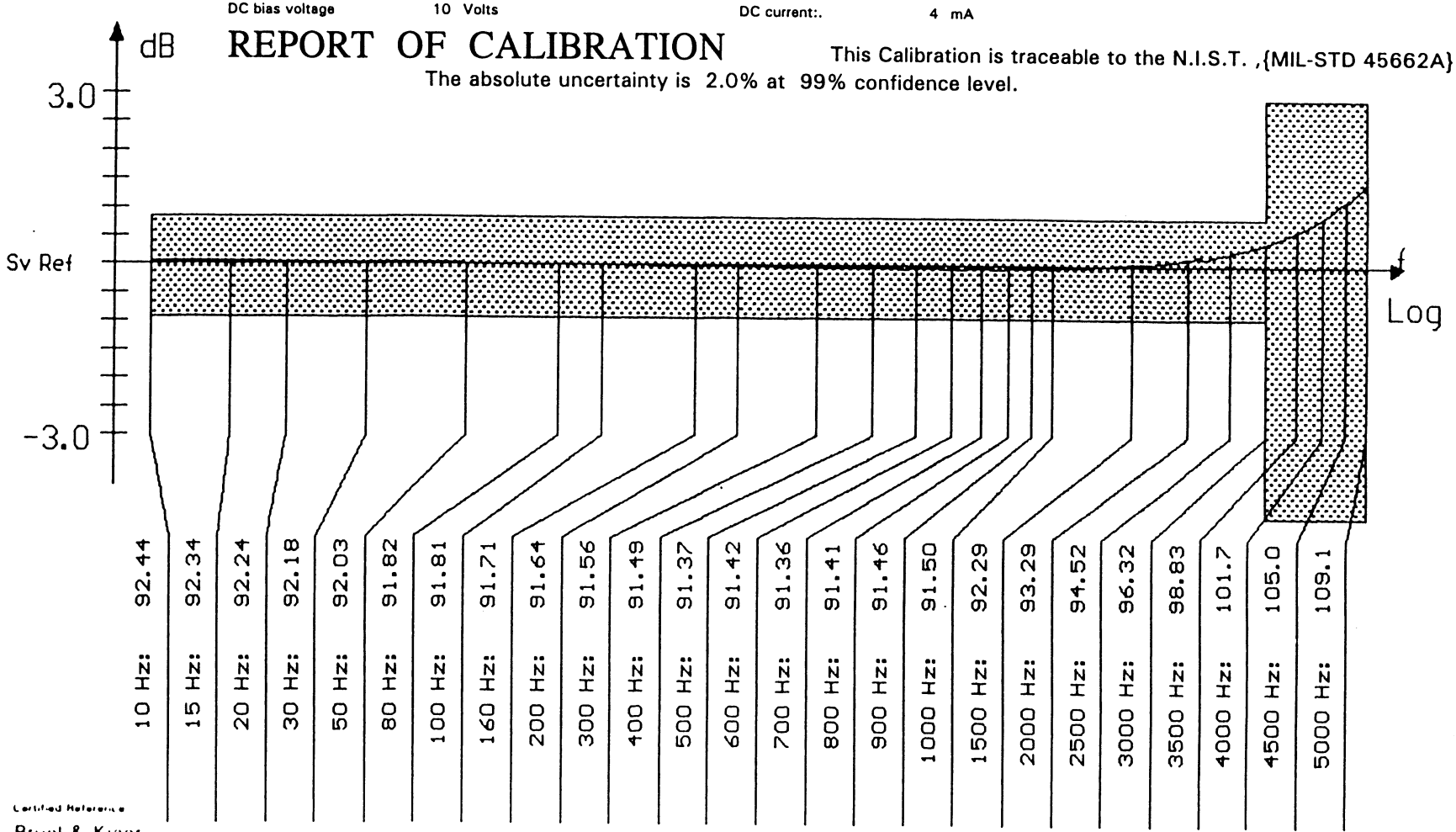
Manufacturer	: PCB	Work Unit Code	: 328A51PCB	Operator ID	: CHRIS
Part No.	: 328A51	Measurement Angle	: 0 °	Calibration Date	: 12 Jan 1995, 13:40
Serial No.	: 17517	Ref. Sensitivity	: Passed	Last Cal. Date	: 14 Feb 1994, 16:57
Freq. range	: 10-5000 Hz	Generator range	: As freq. range		

DC bias voltage 10 Volts DC current:. 4 mA

REPORT OF CALIBRATION

This Calibration is traceable to the N.I.S.T. ,{MIL-STD 45662A}

The absolute uncertainty is 2.0% at 99% confidence level.



Certified Reference
Bruel & Kjaer
8305
S/N 1777437

Ref. Sensitivity @ 100Hz: 91.81 mV/g

Date of Cal. July 18,94 Due Date July 18,95 NIST Test No. 822/253333-94

TORSIOGRAPH CALIBRATION

Jan 17, 1995 - NKF Torsiograph S/N 11

Raw Data Points:

$$TG1 := \begin{bmatrix} 0 & 0 \\ 1 & .00015 \\ 3 & .0010 \\ 4.5 & .0032 \\ 5.5 & .00442 \\ 7 & .00330 \\ 9 & .00255 \\ 15 & .00201 \\ 20 & .00184 \\ 25 & .00178 \\ 30 & .00176 \\ 50 & .0017 \\ 70 & .00165 \\ 90 & .00168 \\ 110 & .00160 \end{bmatrix}$$

UNITS: Volt-Sec/Deg

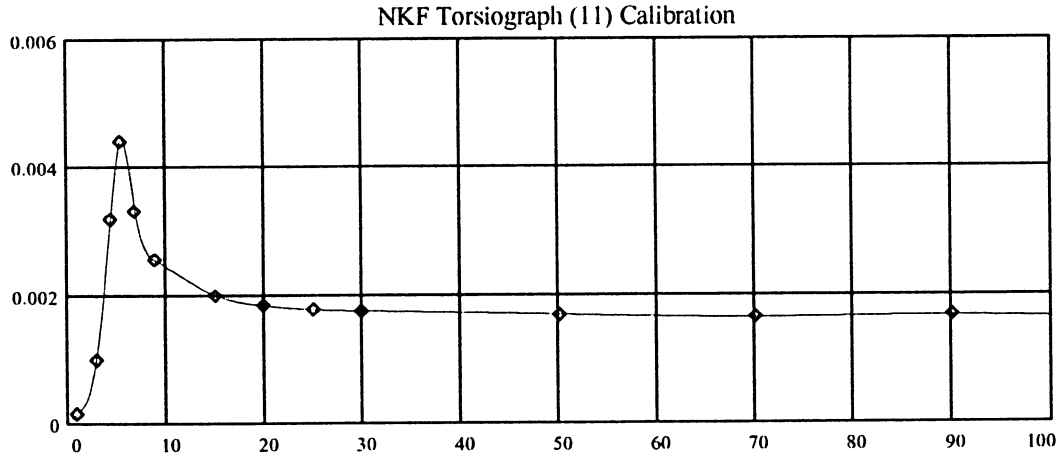
$nrow := rows(TG1) - 1 \quad j := 1 .. nrow$

Generate a spline fit to data:

$npt := 400 \quad i := 1 .. npt \qquad f_{max} := 100 \qquad f_i := \frac{i}{npt} \cdot f_{max}$

$vs1 := lspline\left(TG1^{\langle 0 \rangle}, TG1^{\langle 1 \rangle}\right)$

$H1_i := interp\left(vs1, TG1^{\langle 0 \rangle}, TG1^{\langle 1 \rangle}, f_i\right)$



$k := 1 .. \frac{npt}{10}$

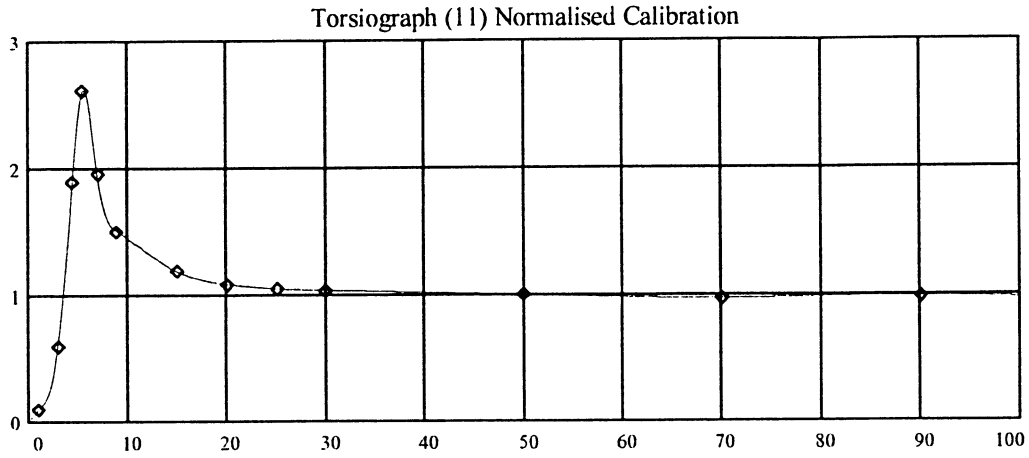
$H\,list_{k-1,1} := \frac{1}{H1_{10 \cdot k}} \qquad H\,list_{k-1,0} := f_{10 \cdot k}$

Normalize Curve to Average above 20 Hz:

$$avg := \frac{\sum_{i=9}^{14} TG1_{i,1}}{6} \qquad avg = 0.001695 \qquad TG1_{j,1} := \frac{TG1_{j,1}}{avg}$$

$$vs1 := lspline\left(TG1^{\langle 0 \rangle}, TG1^{\langle 1 \rangle}\right)$$

$$H1_i := interp\left(vs1, TG1^{\langle 0 \rangle}, TG1^{\langle 1 \rangle}, f_i\right)$$



PCB®
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"Helping you make better dynamic measurements."

HAND - HELD CALIBRATOR

Model No.: **394B06**
Serial No.: **689**

Operating Frequency (± 1%)	**79.6** Hz.
Acceleration (± 3%)	**1.00** g's rms

1 g rms = 1.414 g's pk
1 g = 9.81 m/s^2

The calibration procedure of PCB Piezotronics is in compliance with MIL-STD-45662A.

Calibration traceable to N.I.S.T. through project No.: **822/253168**

By : John P. Tuck

Date : 3-9-95

PCB Piezotronics, Inc.
3425 Walden Avenue Depew, New York 14043-2495
Phone: 716-684-0001 FAX: 716-684-0987

CALIBRATION CERTIFICATE

No. 19870

The instrument listed below has been calibrated to specifications. The calibration standards used are traceable to the National Institute of Standards and Technology. Applicable traceability records are kept at the address below for inspection.

Fluke 8060A	3735408	
(instrument model)	(serial No.)	
T.D. Keepers	January 10, 1995	1 yr
(certified by)	(date)	(interval)

Status		Environment	
(X) In tolerance	(X) In tolerance		
Received ( ) Out of tolerance	Returned ( ) Limited _____	20	C°
( ) Operational failure	_____	43	%RH

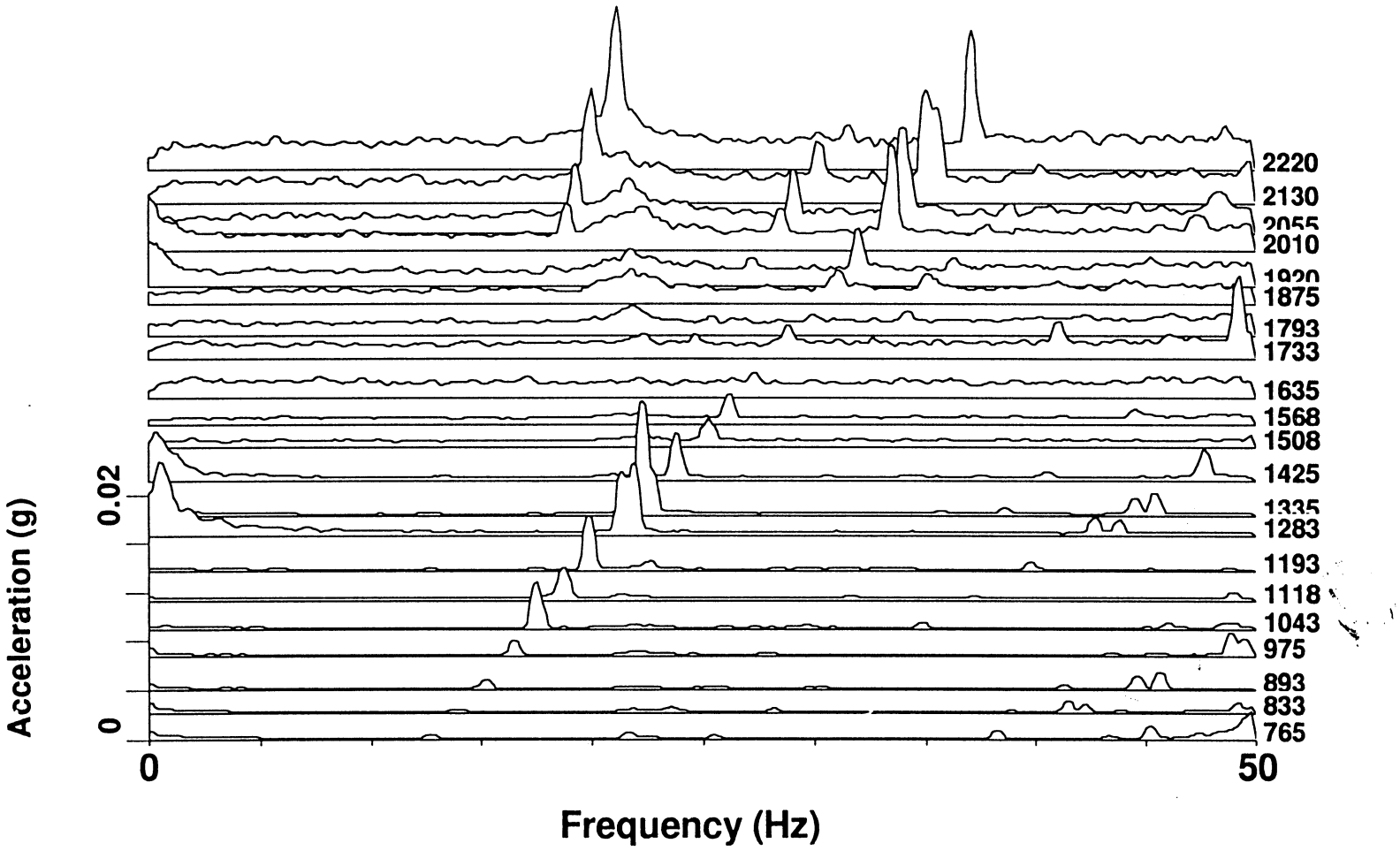
CALIBRATIONS UNLIMITED INC.
1905 Flint Hill Road
Silver Spring, MD 20906
301 598-3110

AC/DC ACS098
RES ACS048 thru ACS052
FREQ VLF WWVB
RF PWR ACS043

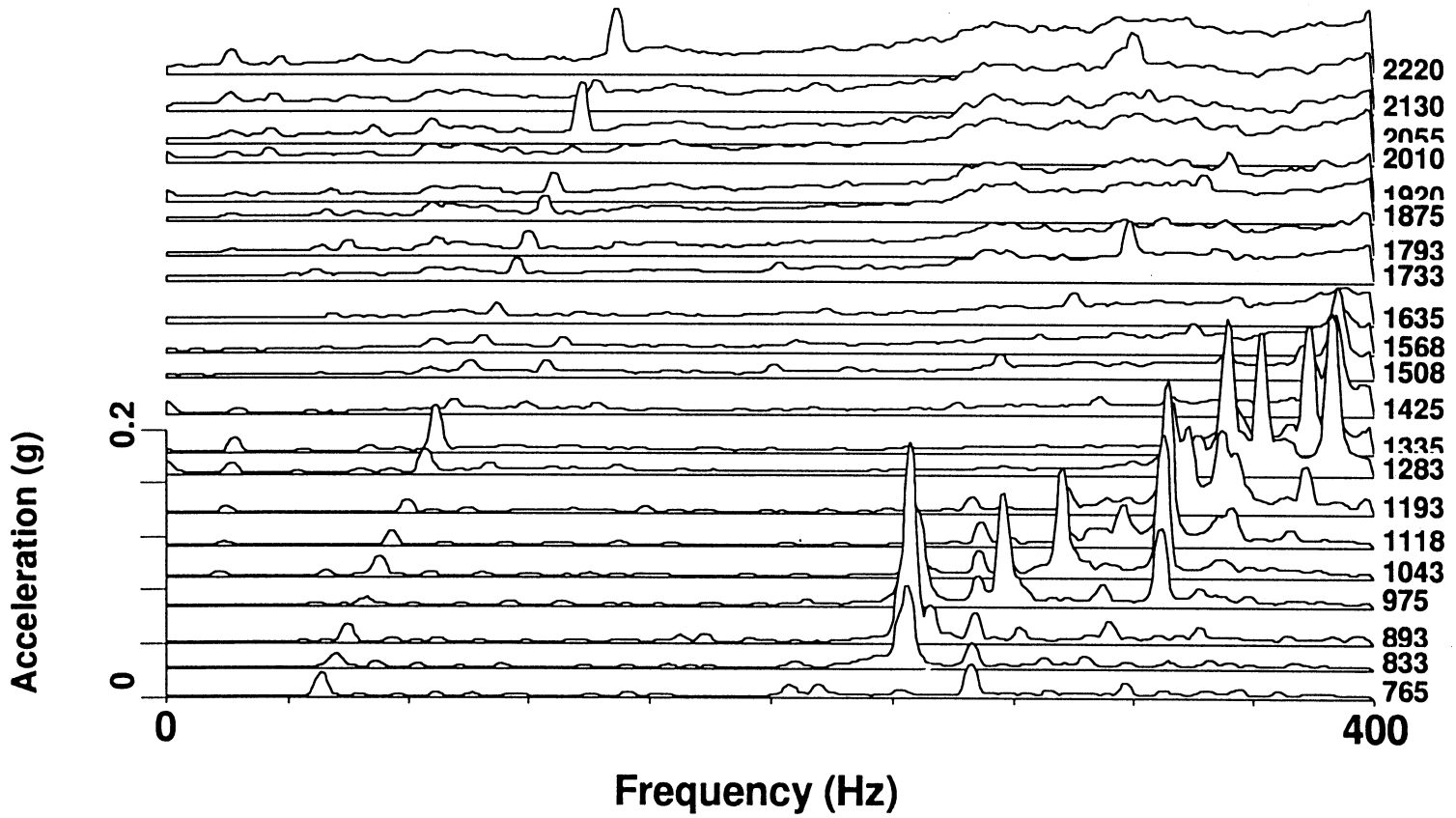
Appendix C

ACCELERATION WATERFALLS

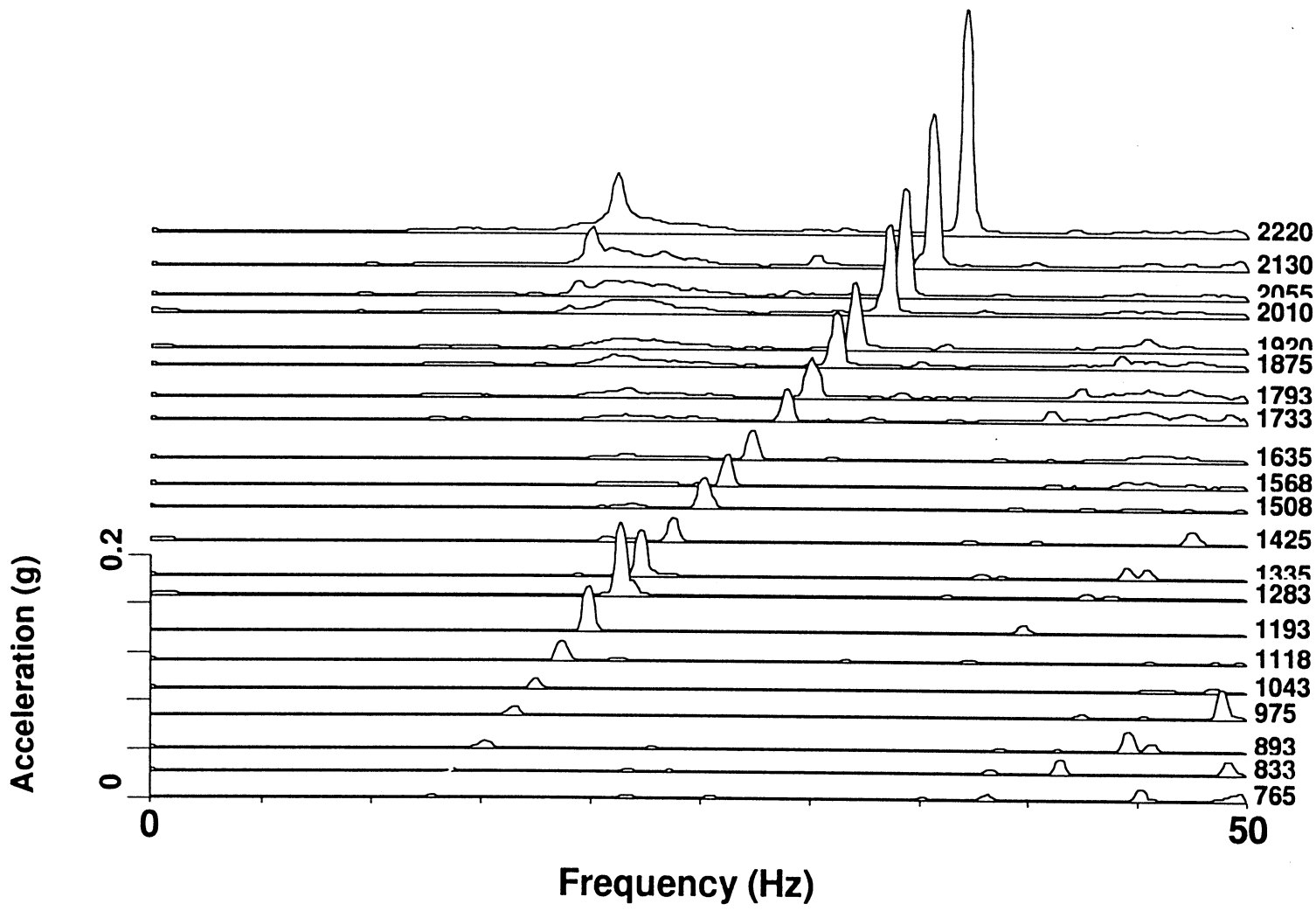
Base of Waterjet (Thruster), Fore/Aft



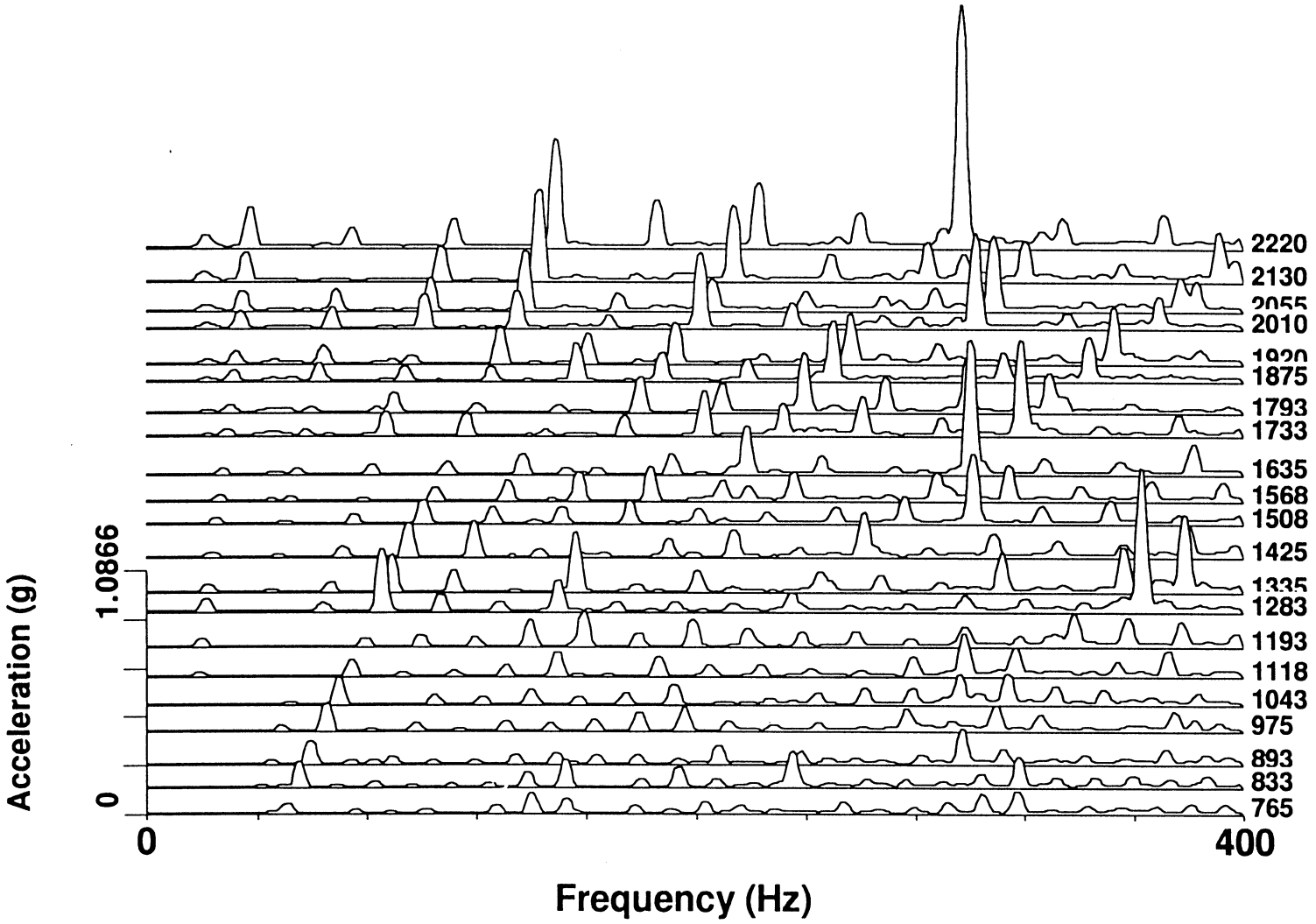
MCF, Base of Waterjet (Thruster), Fore/Aft



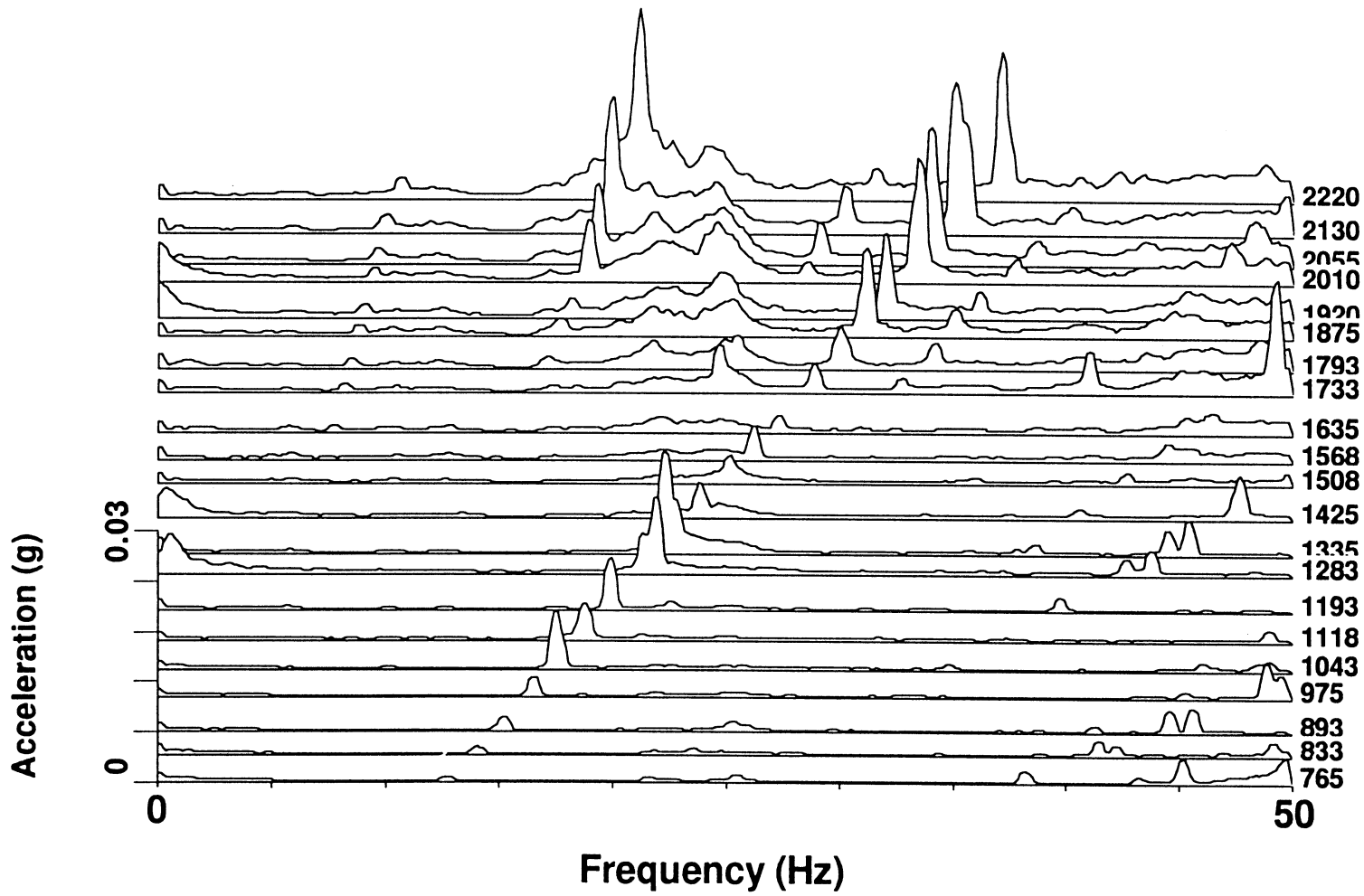
Base of Engine, Vertical



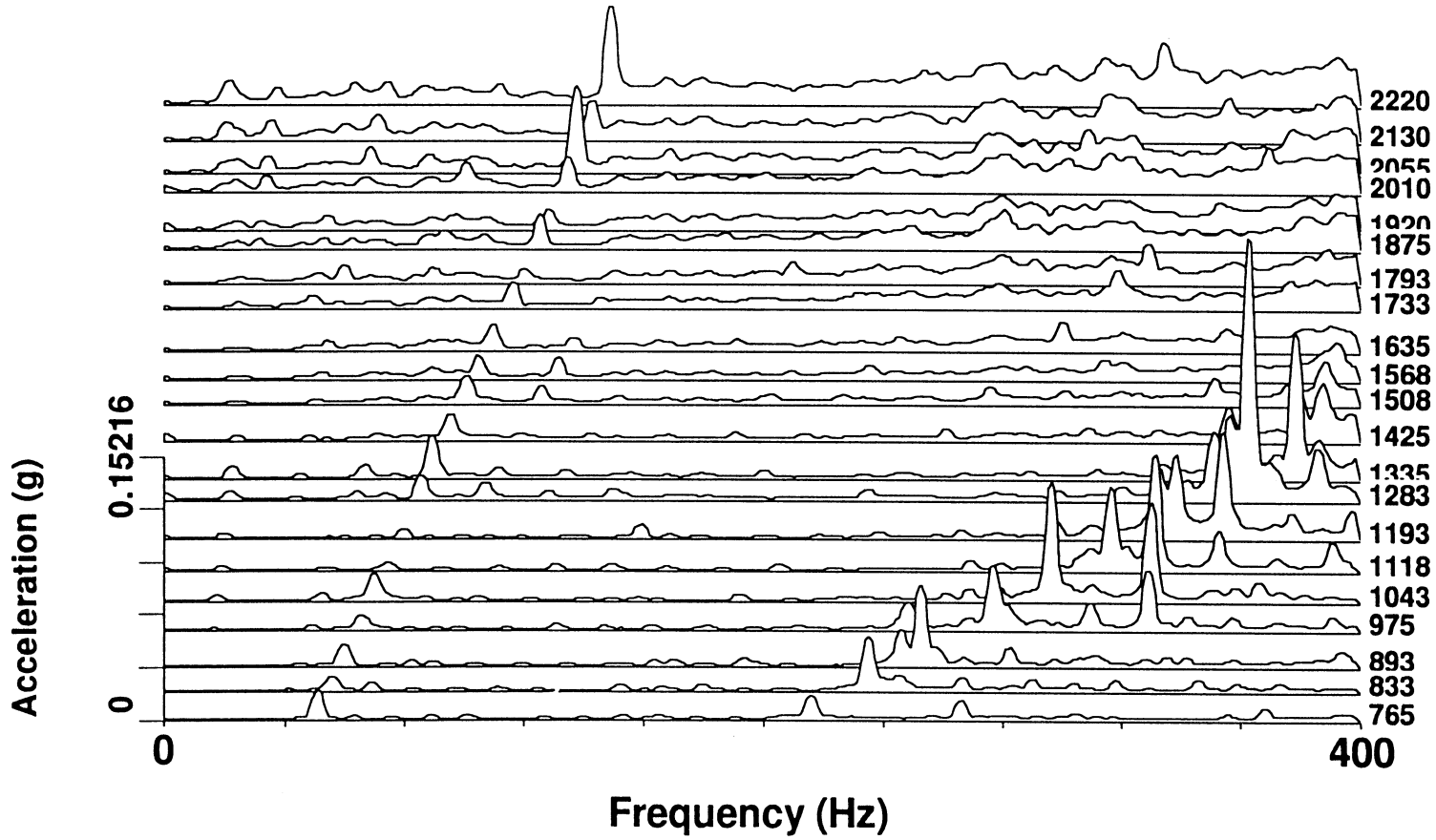
MCF, Base of Engine, Vertical



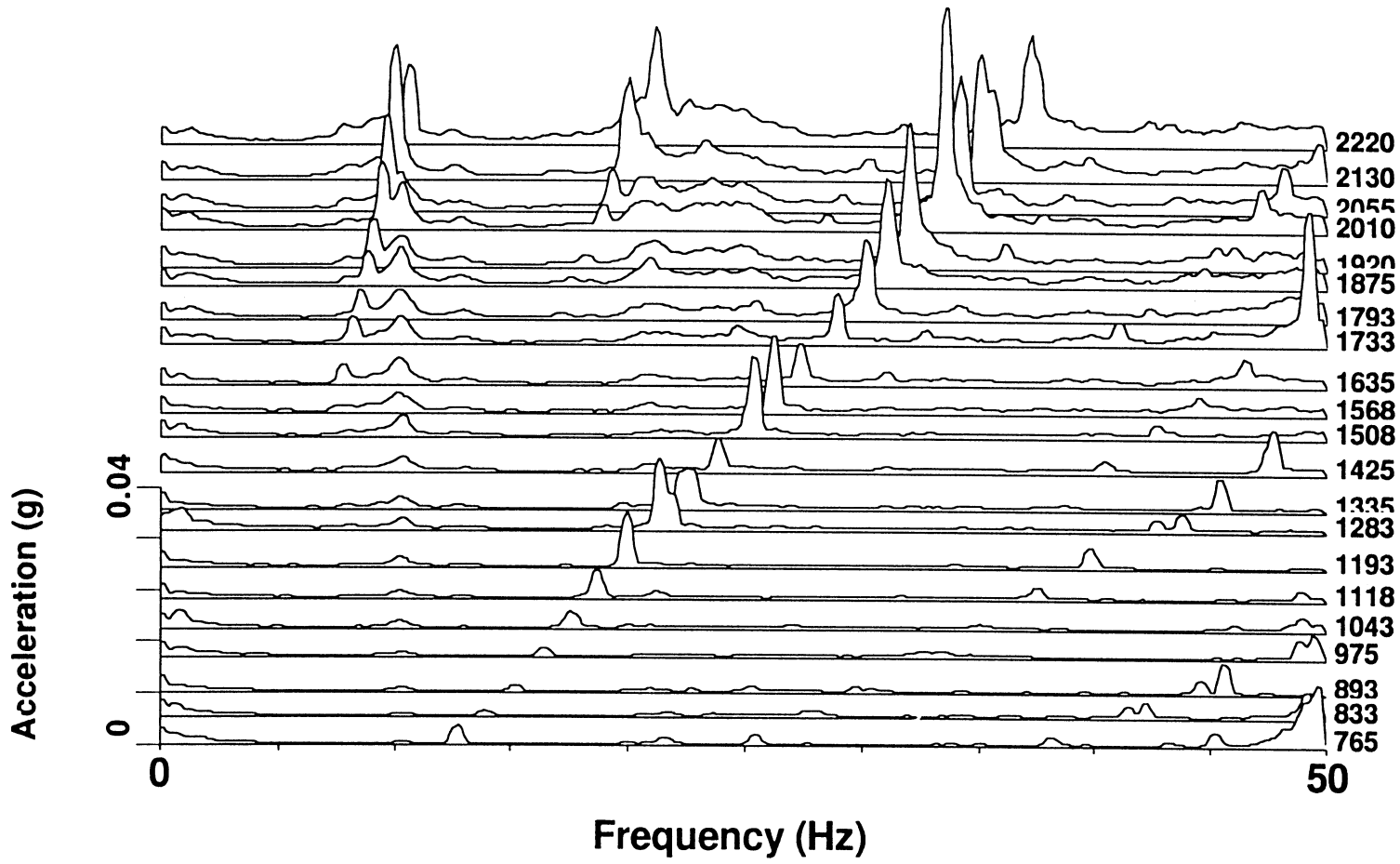
Hull Stern, Fore/Aft



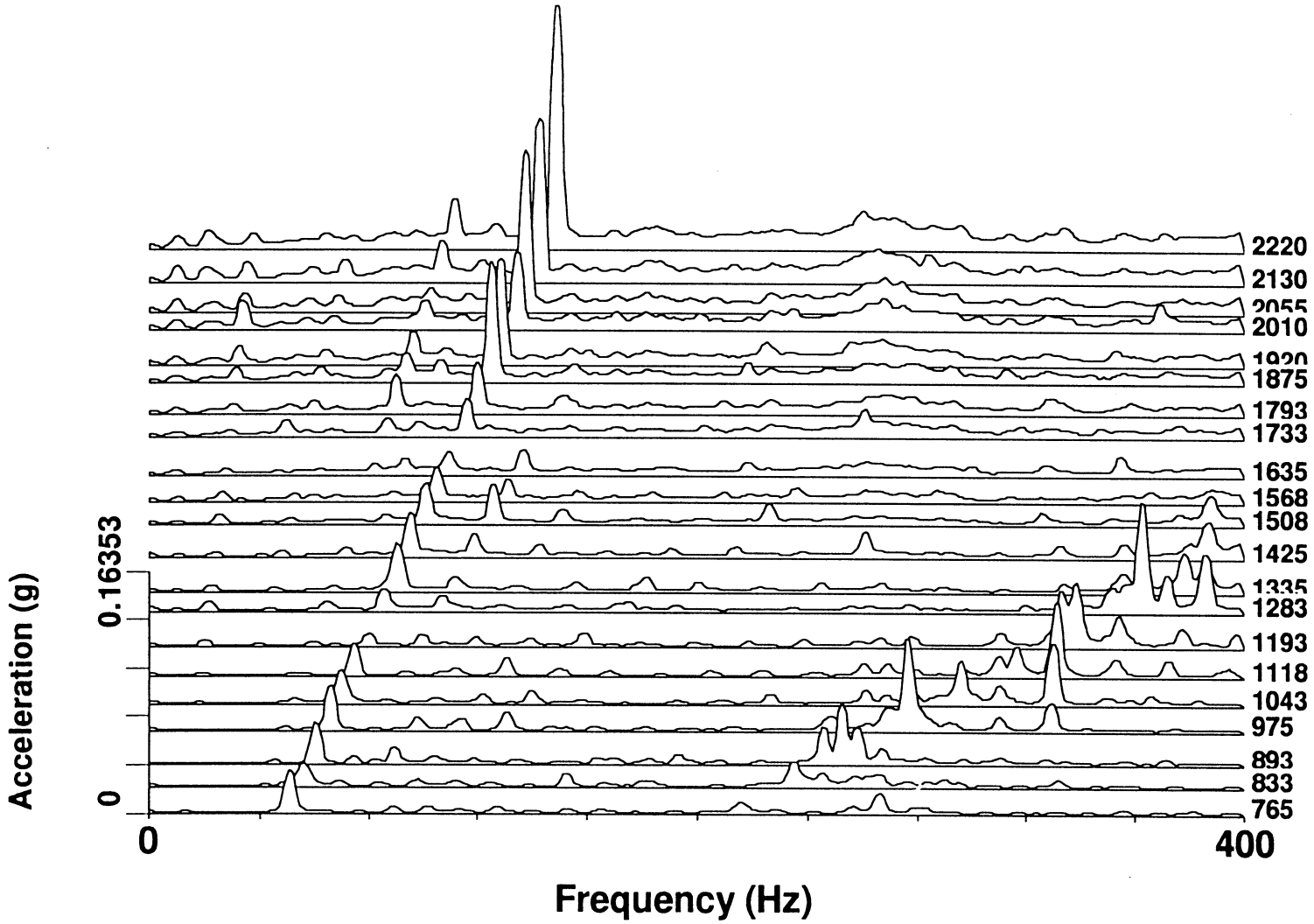
MCF, Hull Stern, Fore/Aft



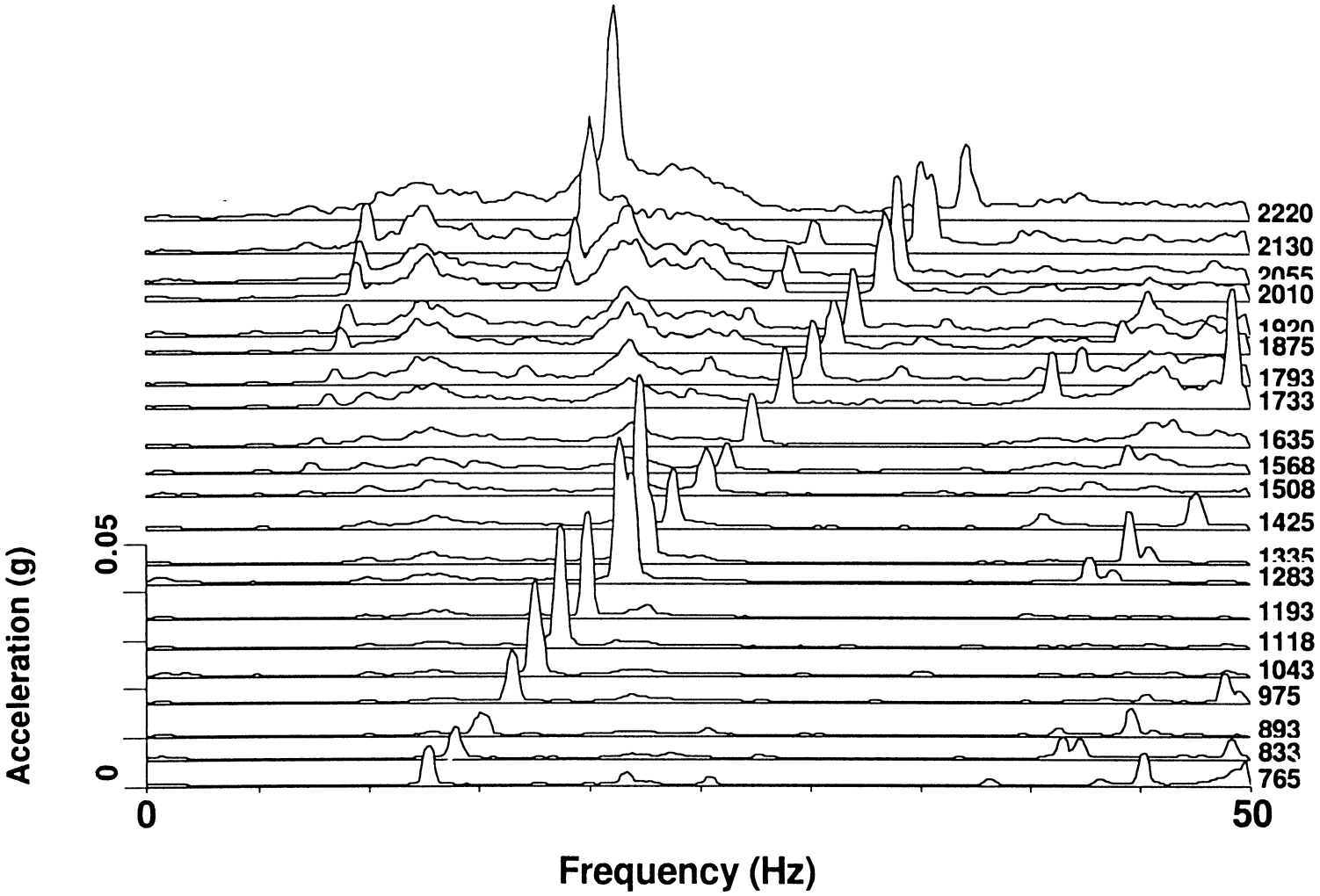
Hull Stern, Athwartship



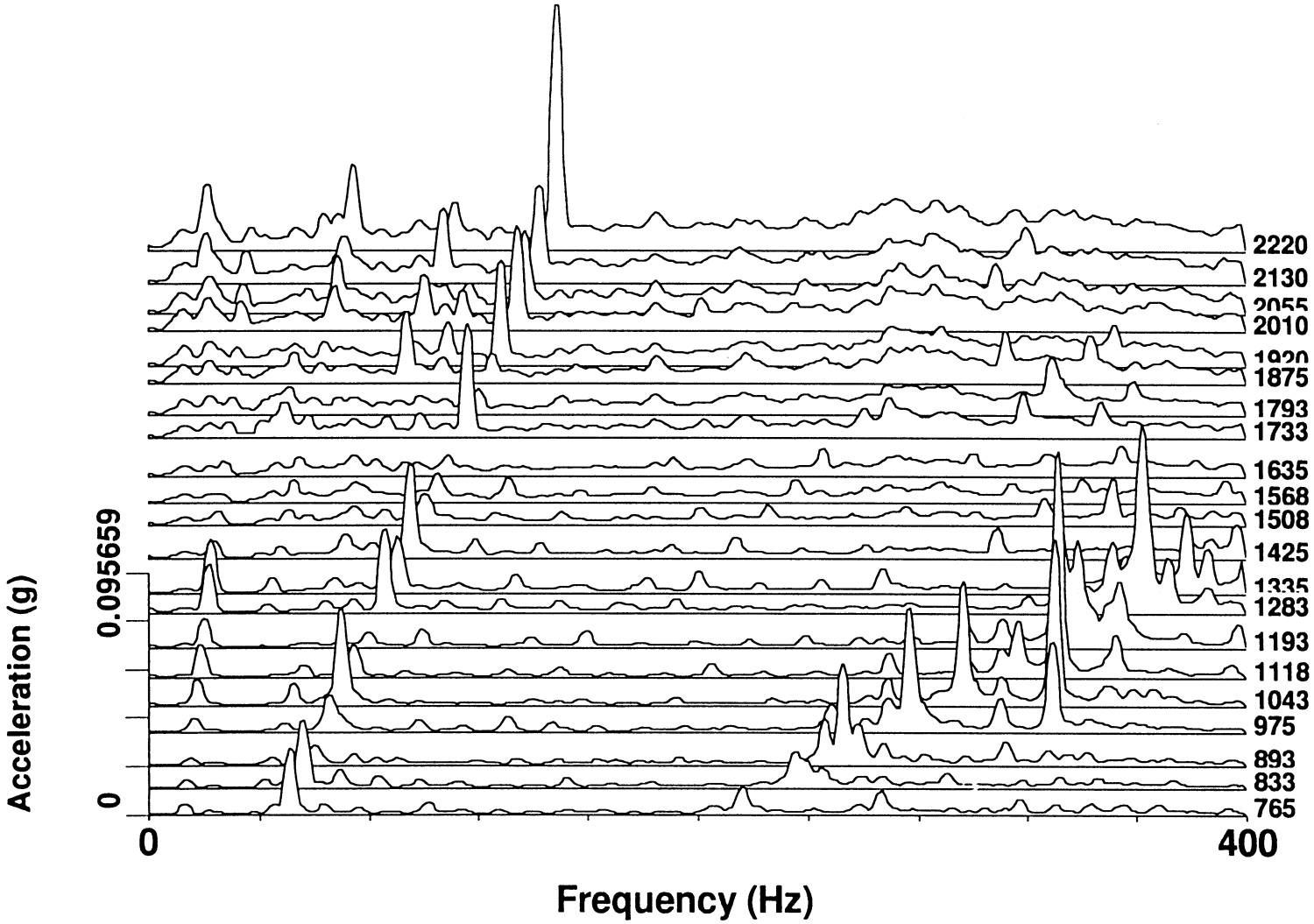
MCF, Hull Stern, Athwartship



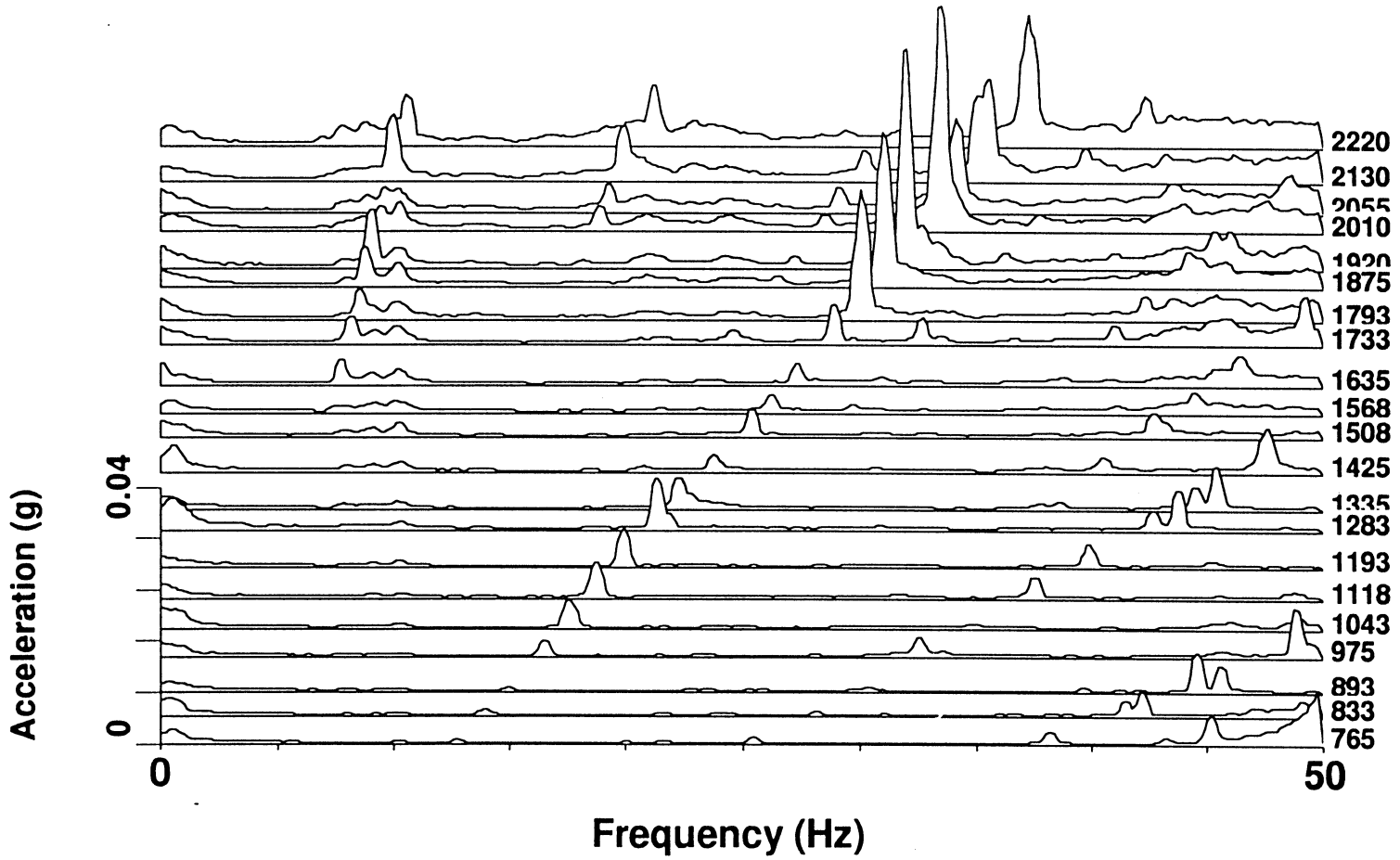
Hull Stern, Vertical



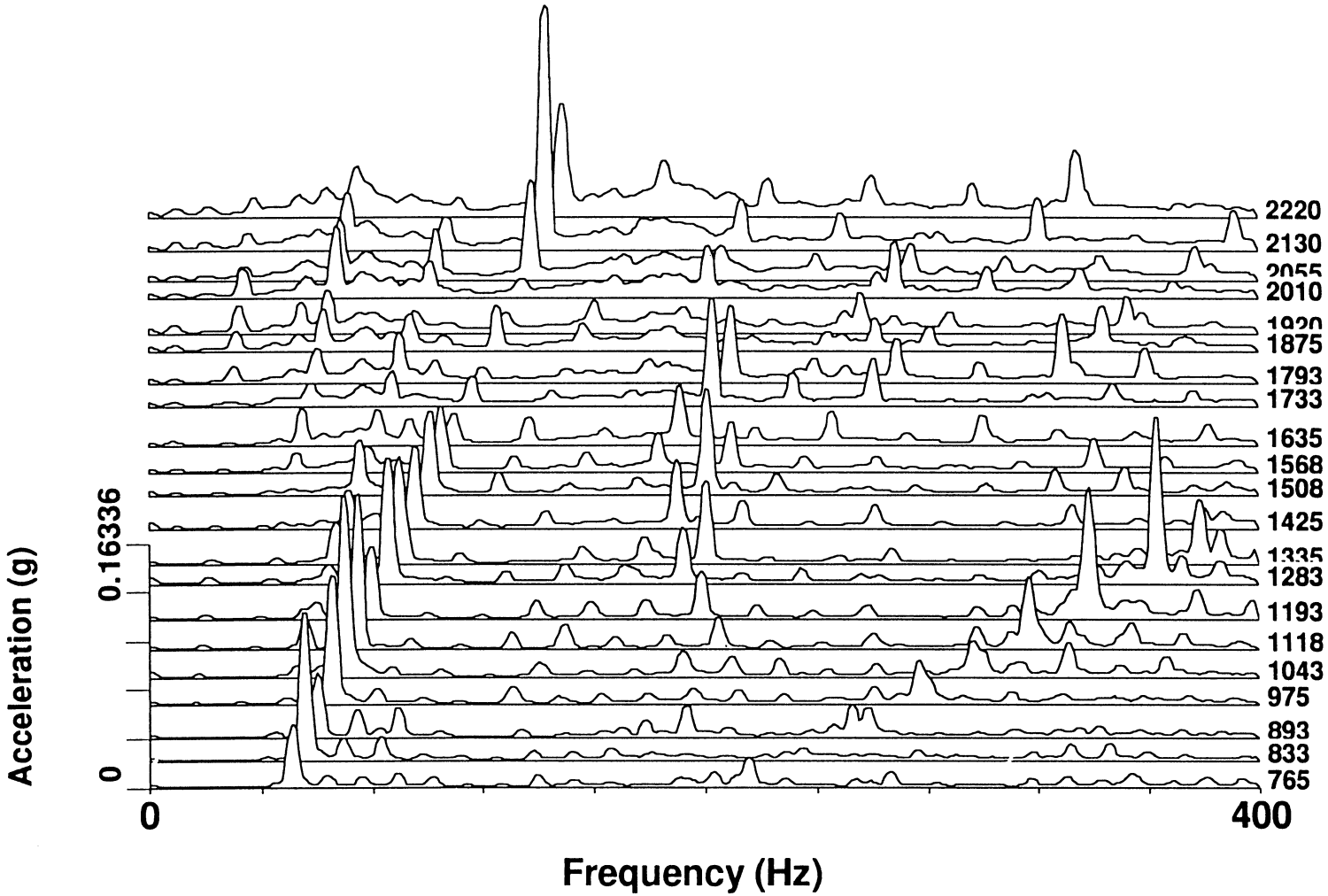
MCF, Hull Stern, Vertical



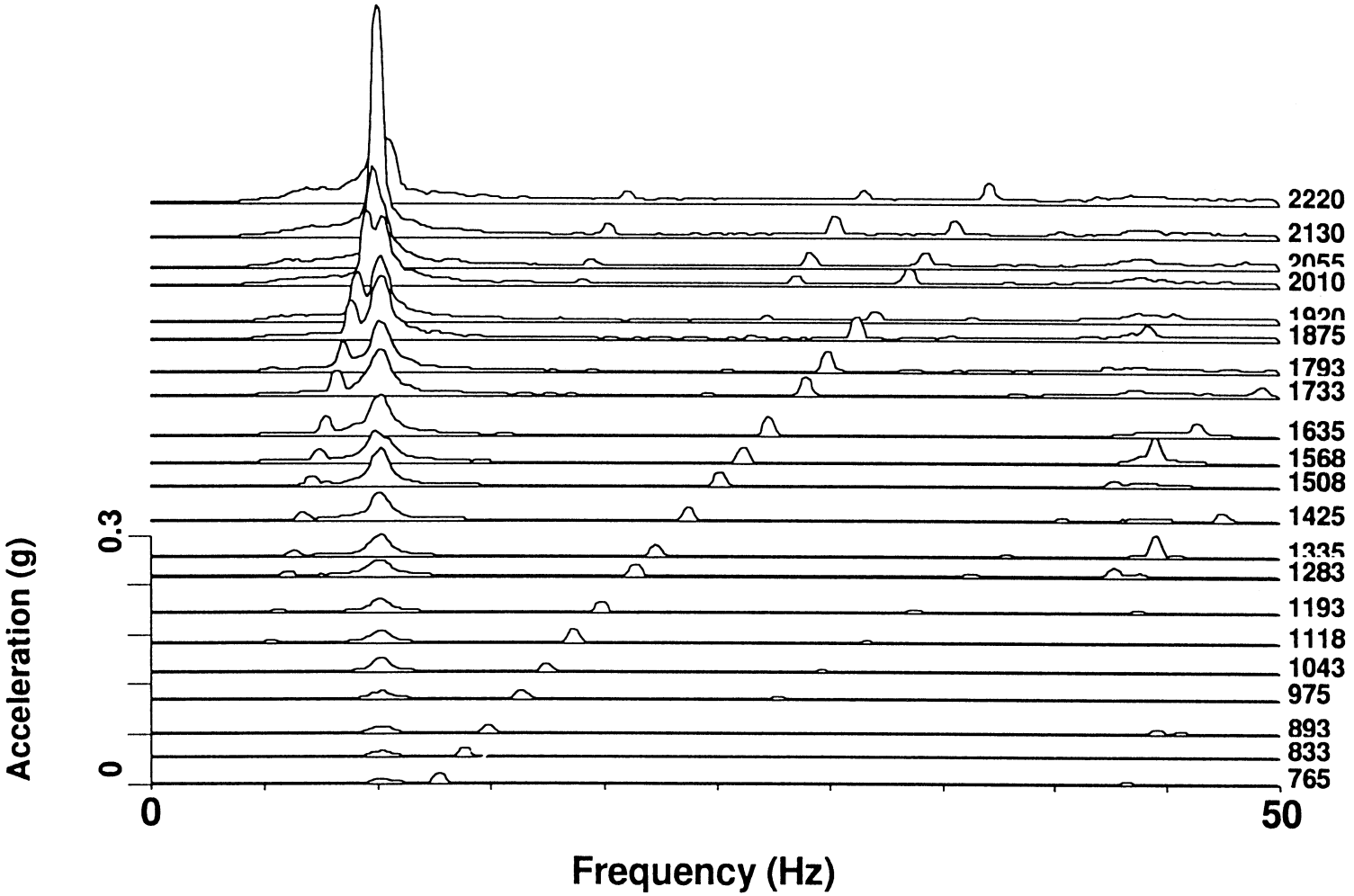
Control Cab, Lower Aft Port Corner, Athwartship



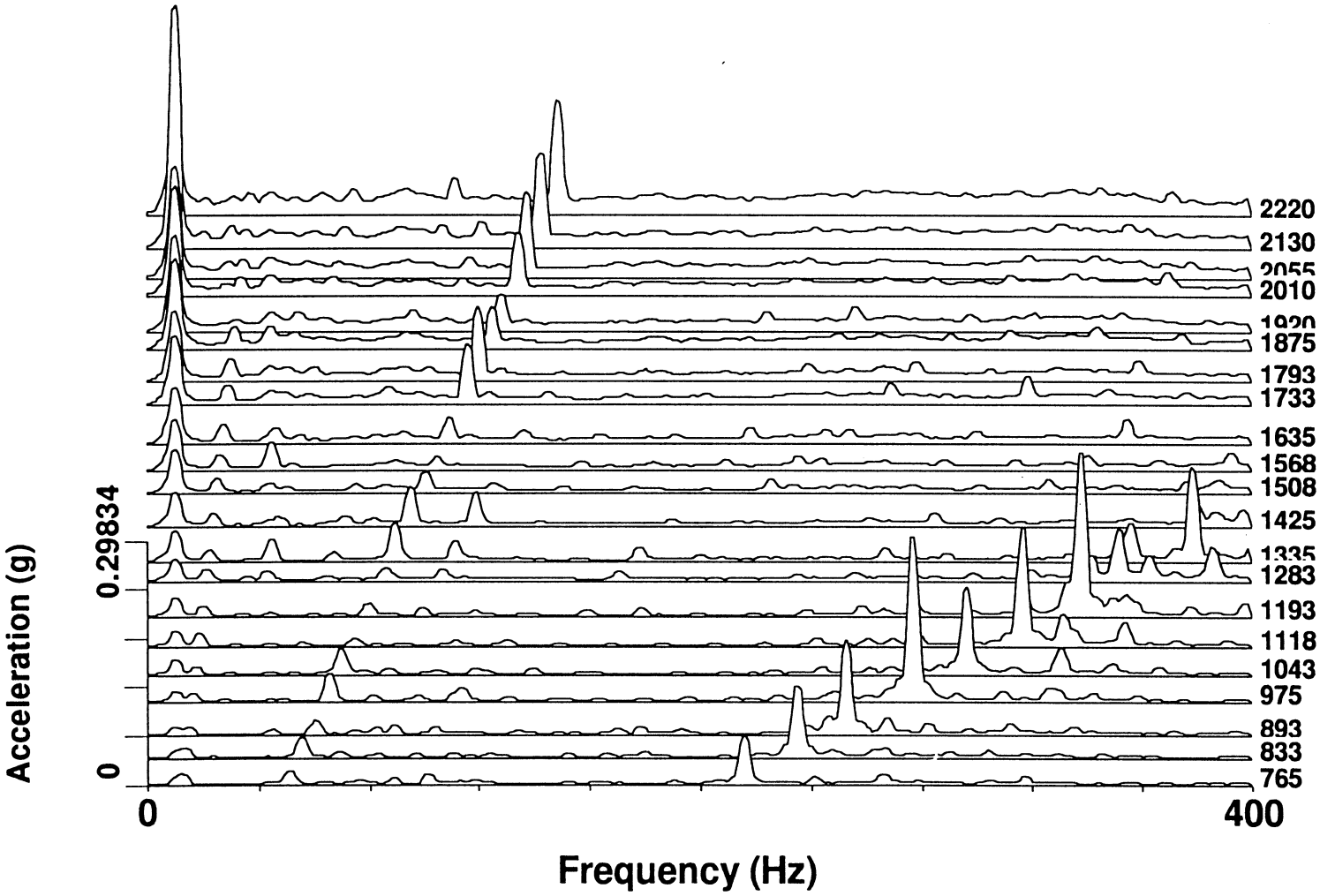
MCF, Control Cab, Lower Aft Port Corner, Athwartship



Top of Water Pump, Athwartship



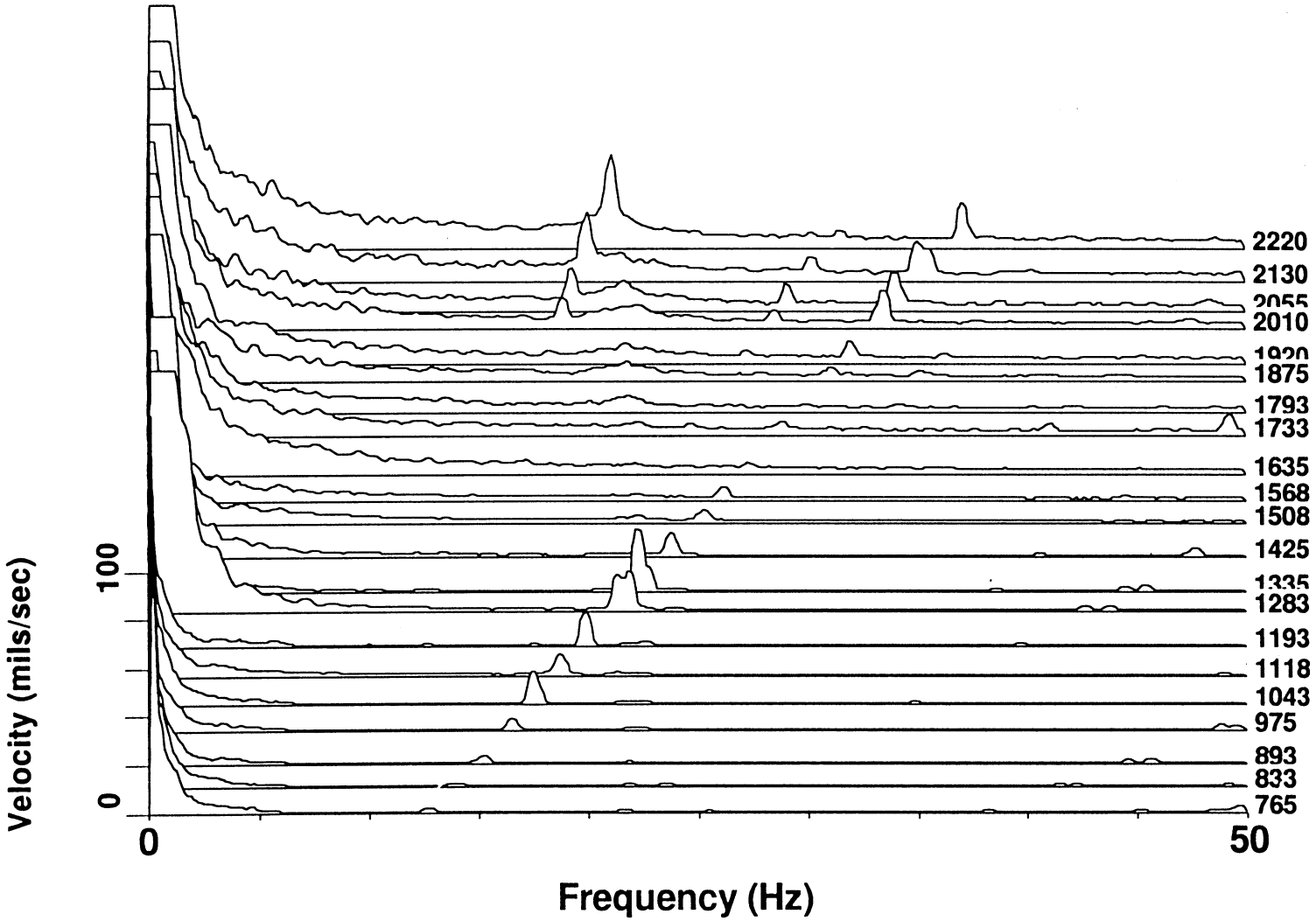
MCF, Top of Water Pump, Athwartship



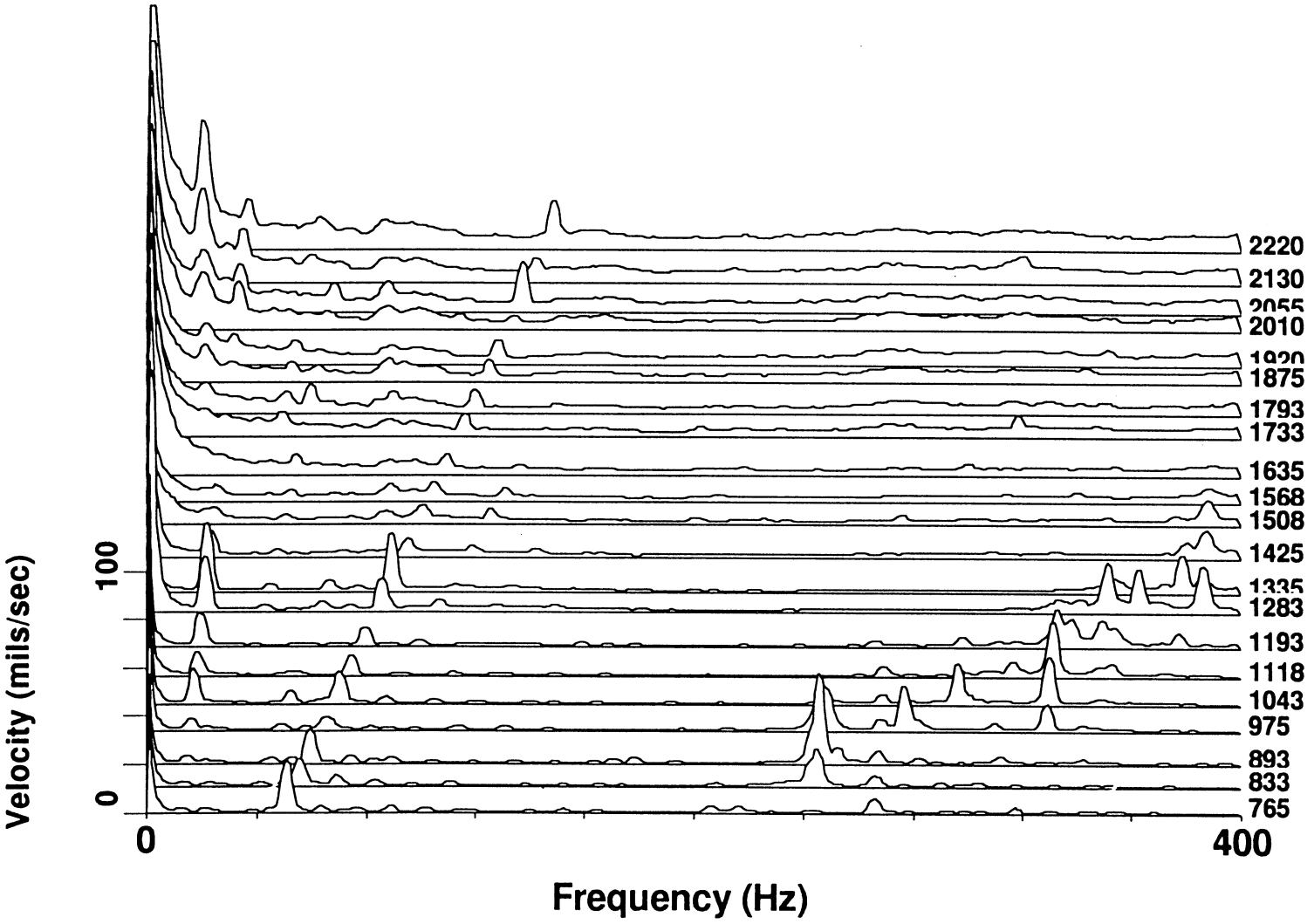
Appendix D

VELOCITY WATERFALLS

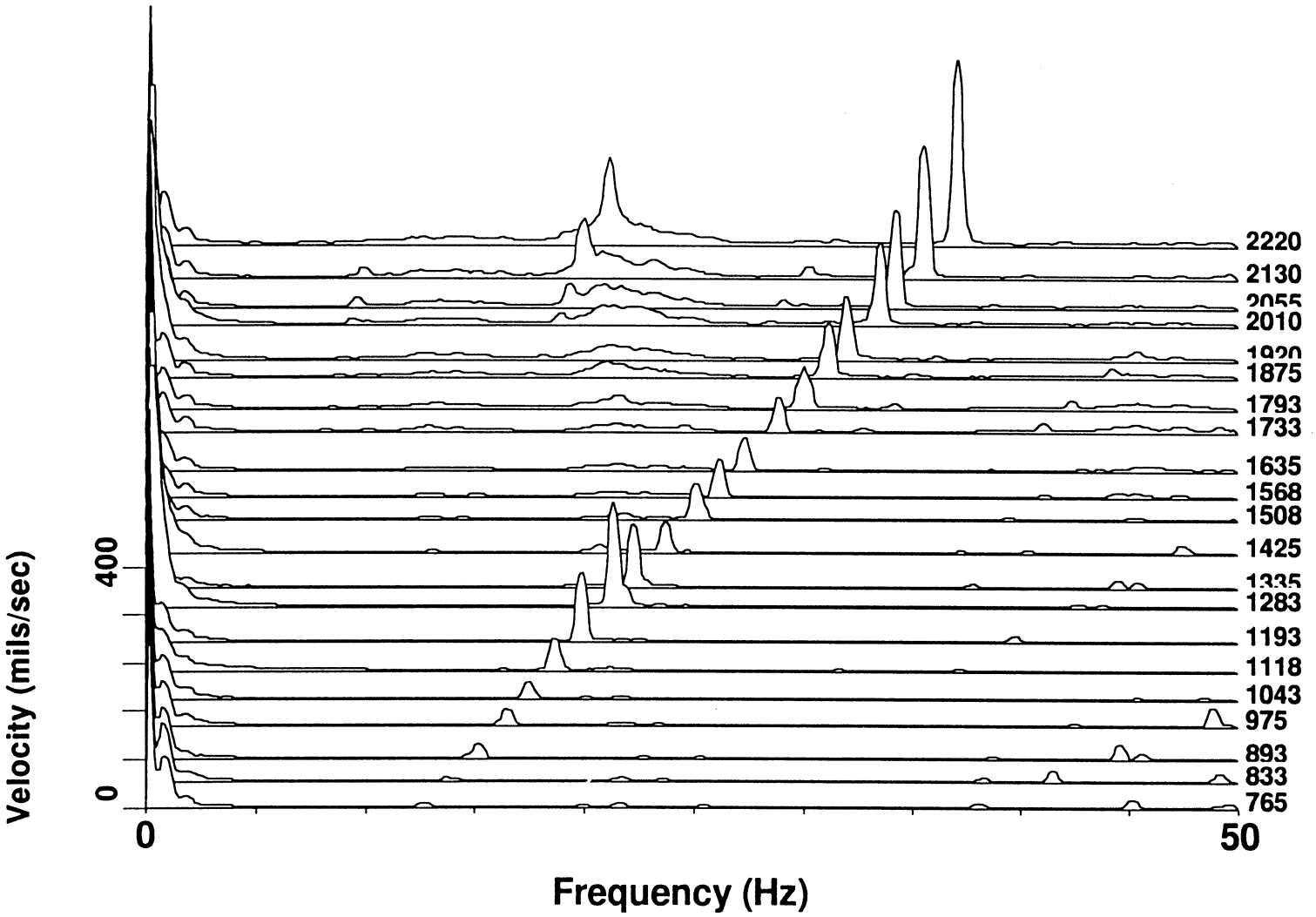
Base of Waterjet (Thruster), Fore/Aft



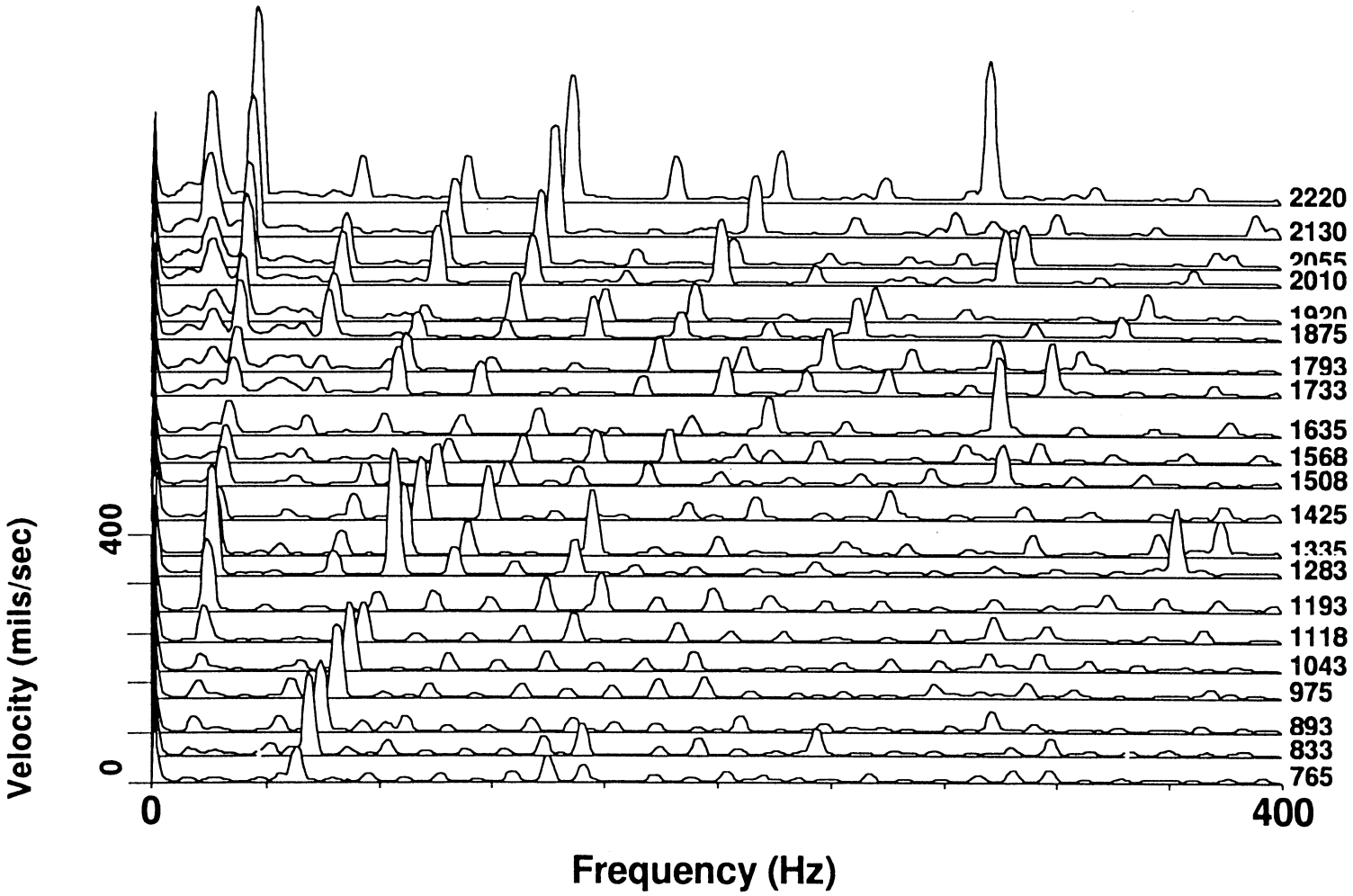
MCF, Base of Waterjet (Thruster), Fore/Aft



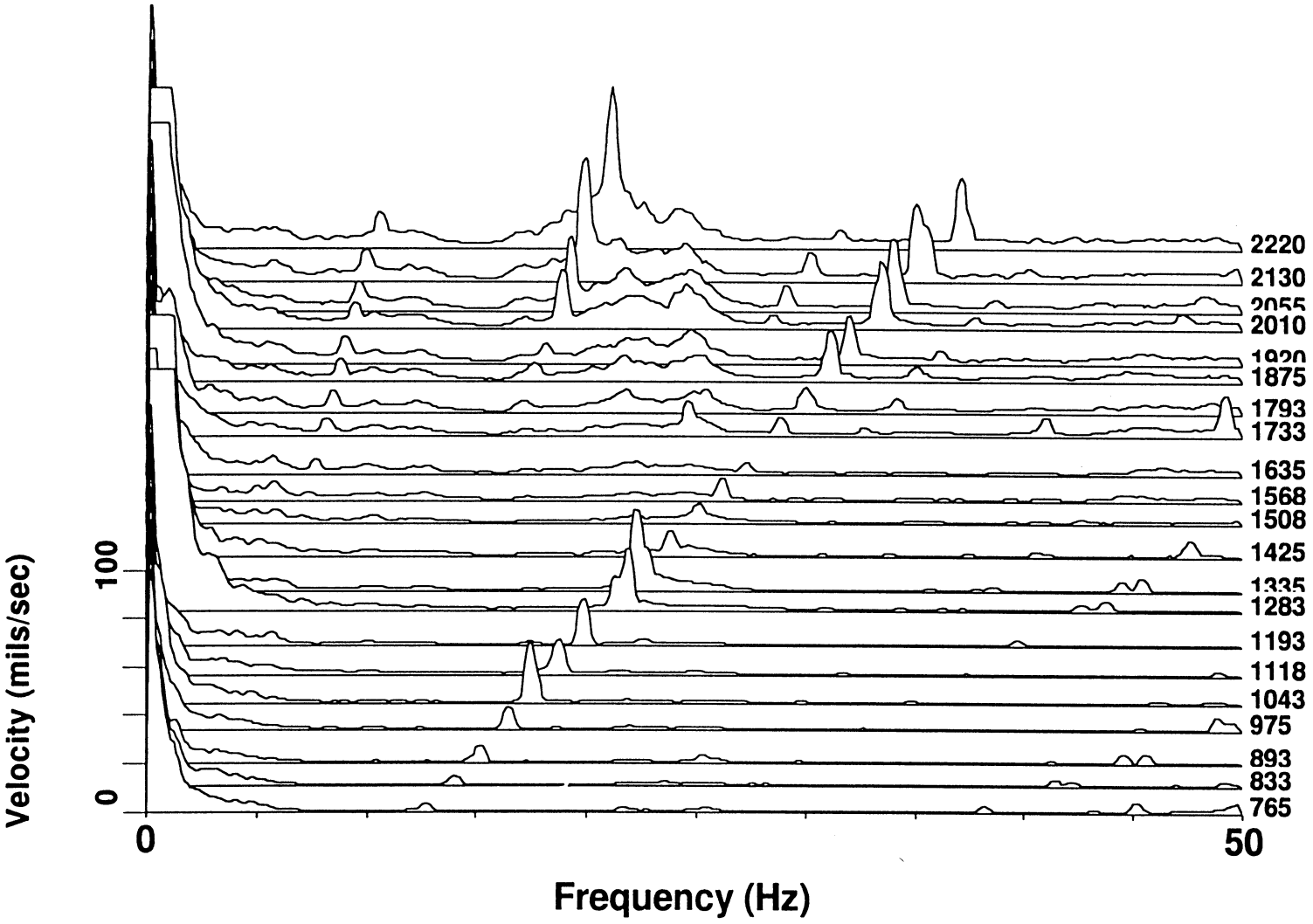
Base of Engine, Vertical



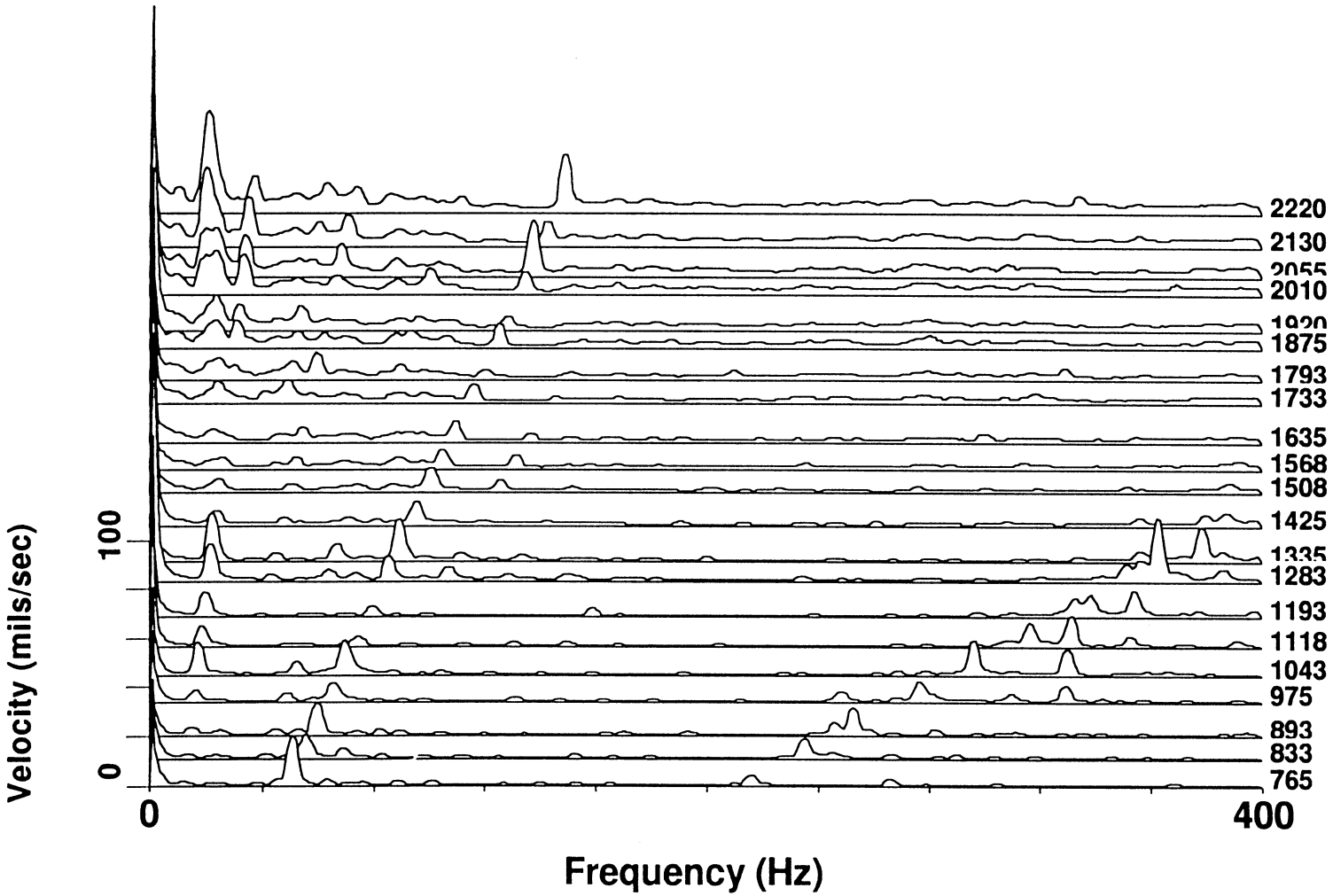
MCF, Base of Engine, Vertical



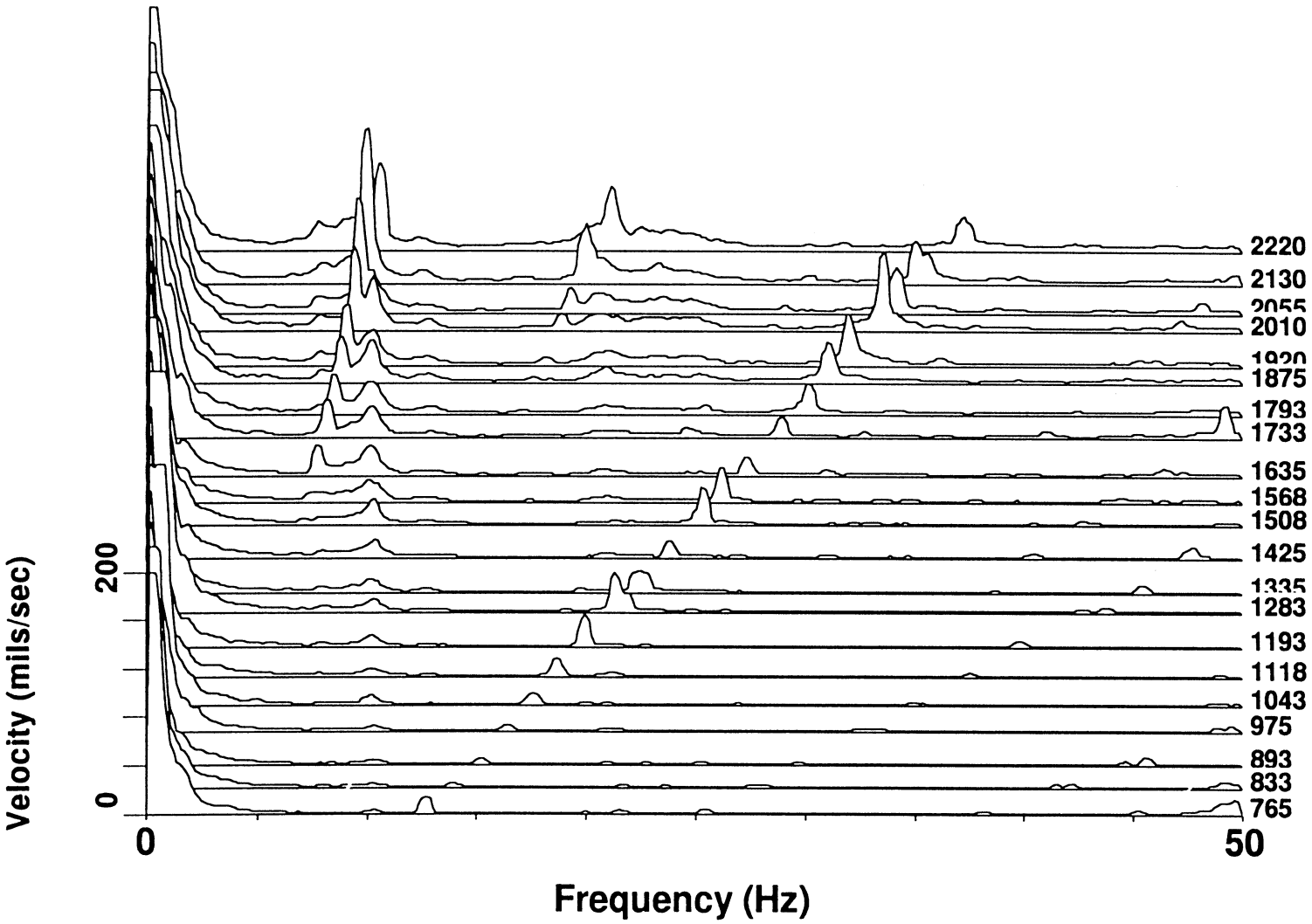
Hull Stern, Fore/Aft



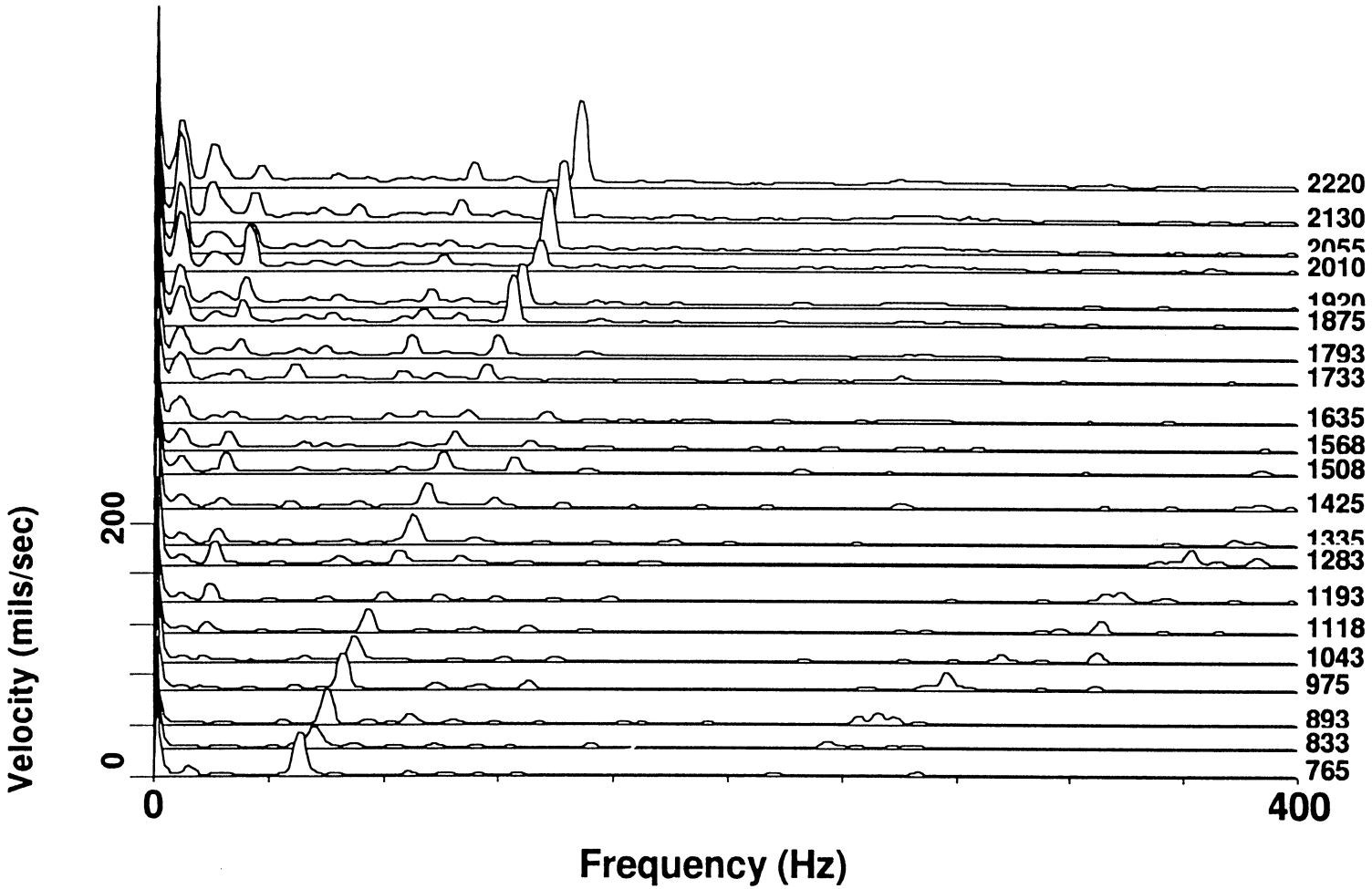
MCF, Hull Stern, Fore/Aft



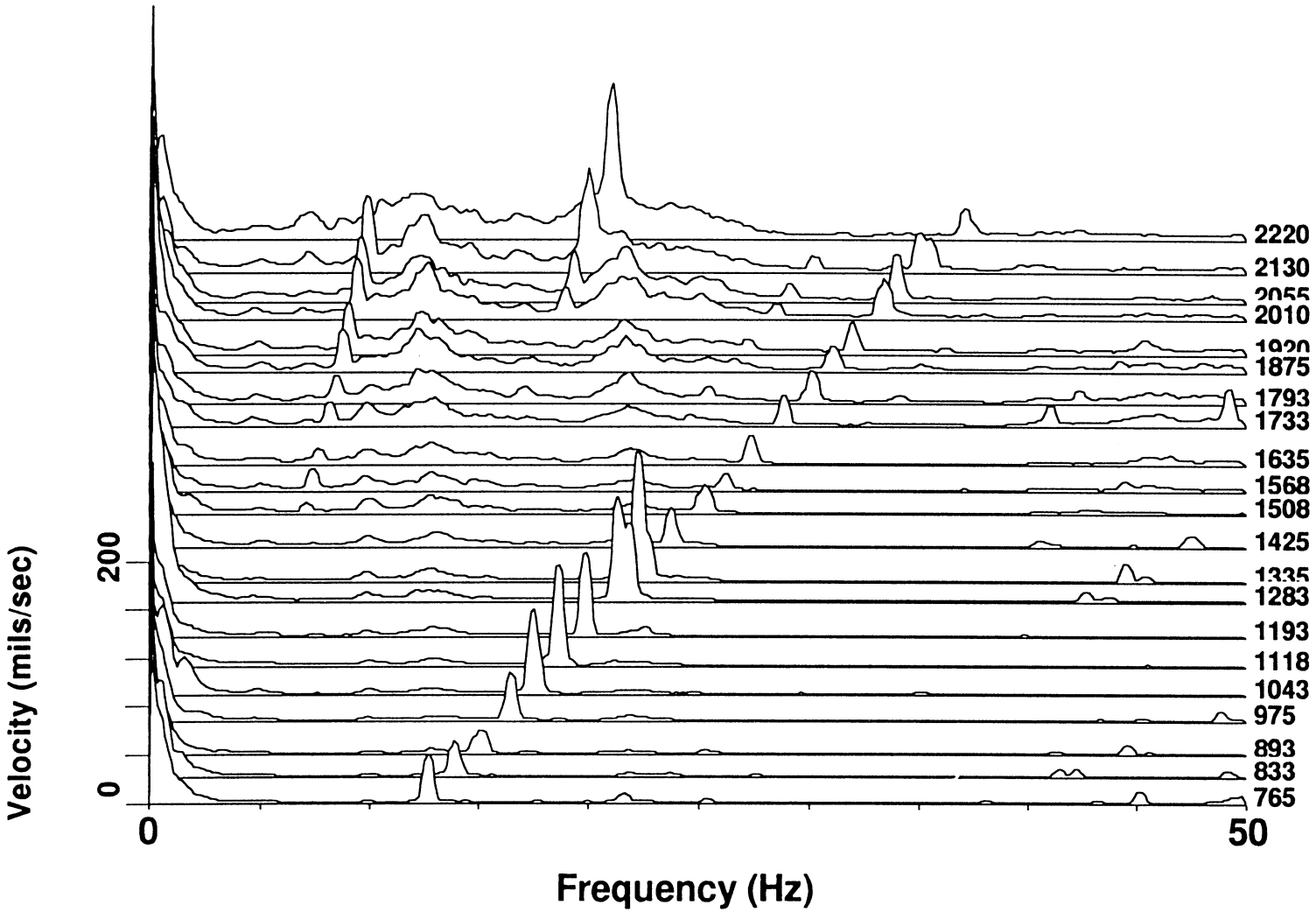
Hull Stern, Athwartship



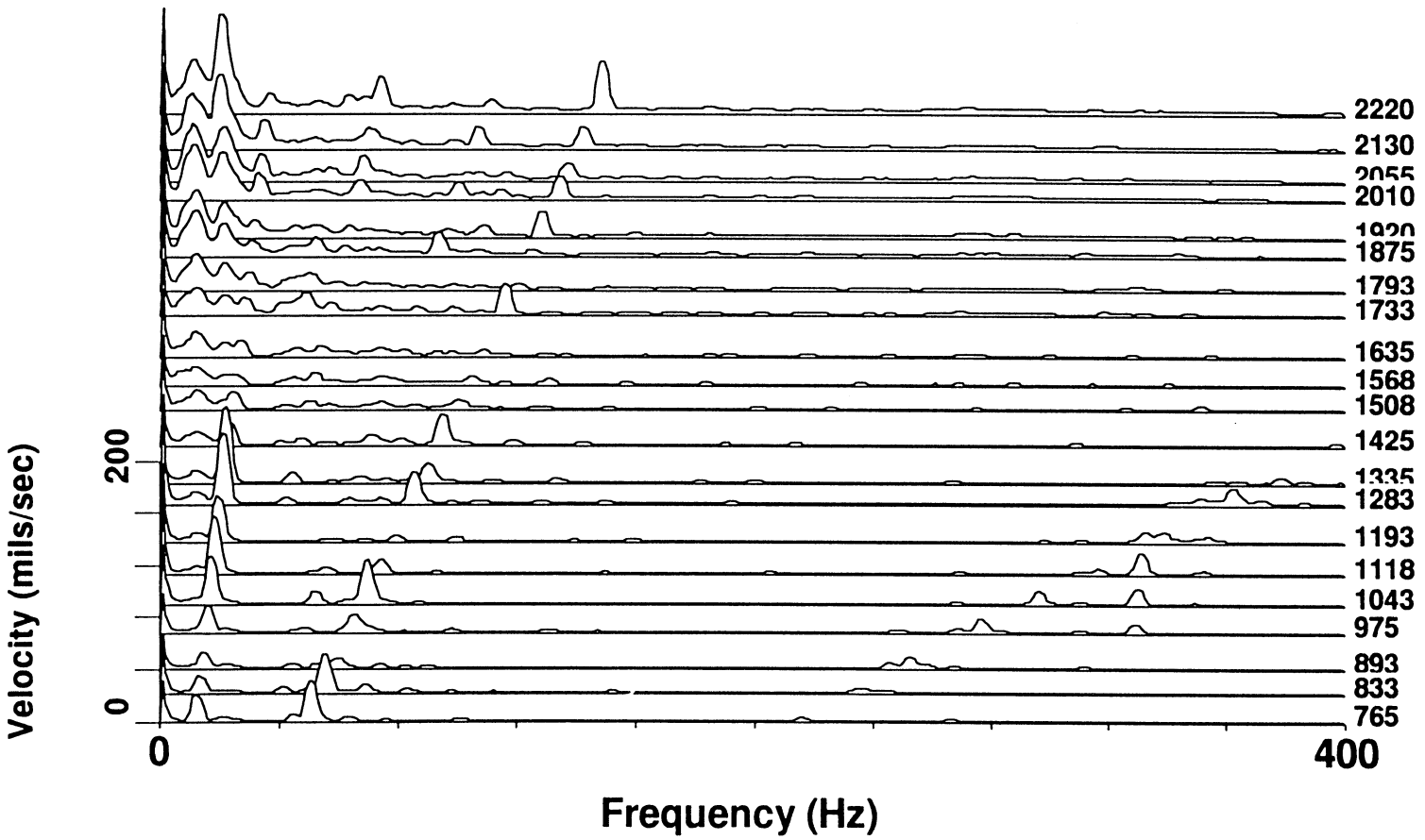
MCF, Hull Stern, Athwartship



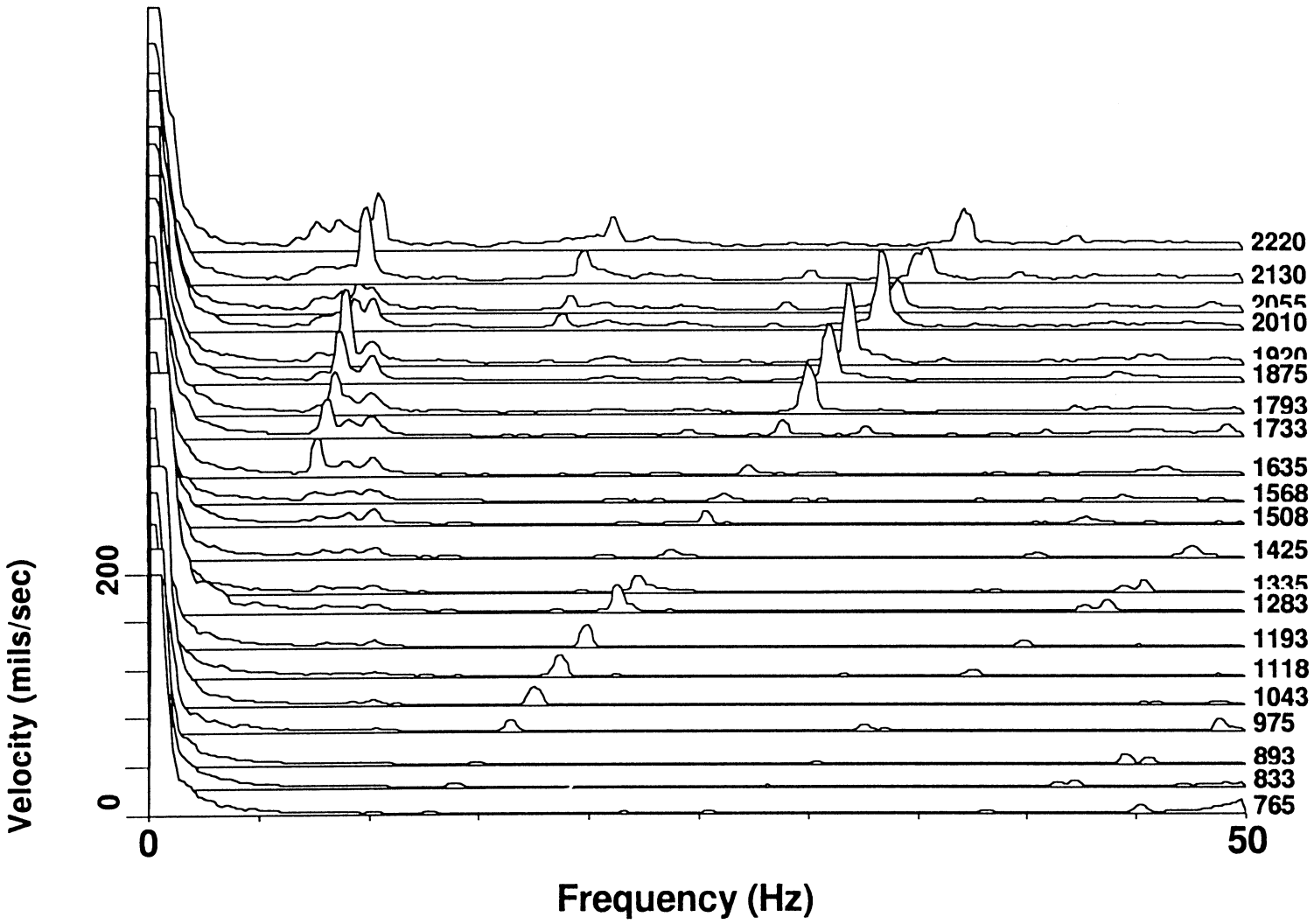
Hull Stern, Vertical



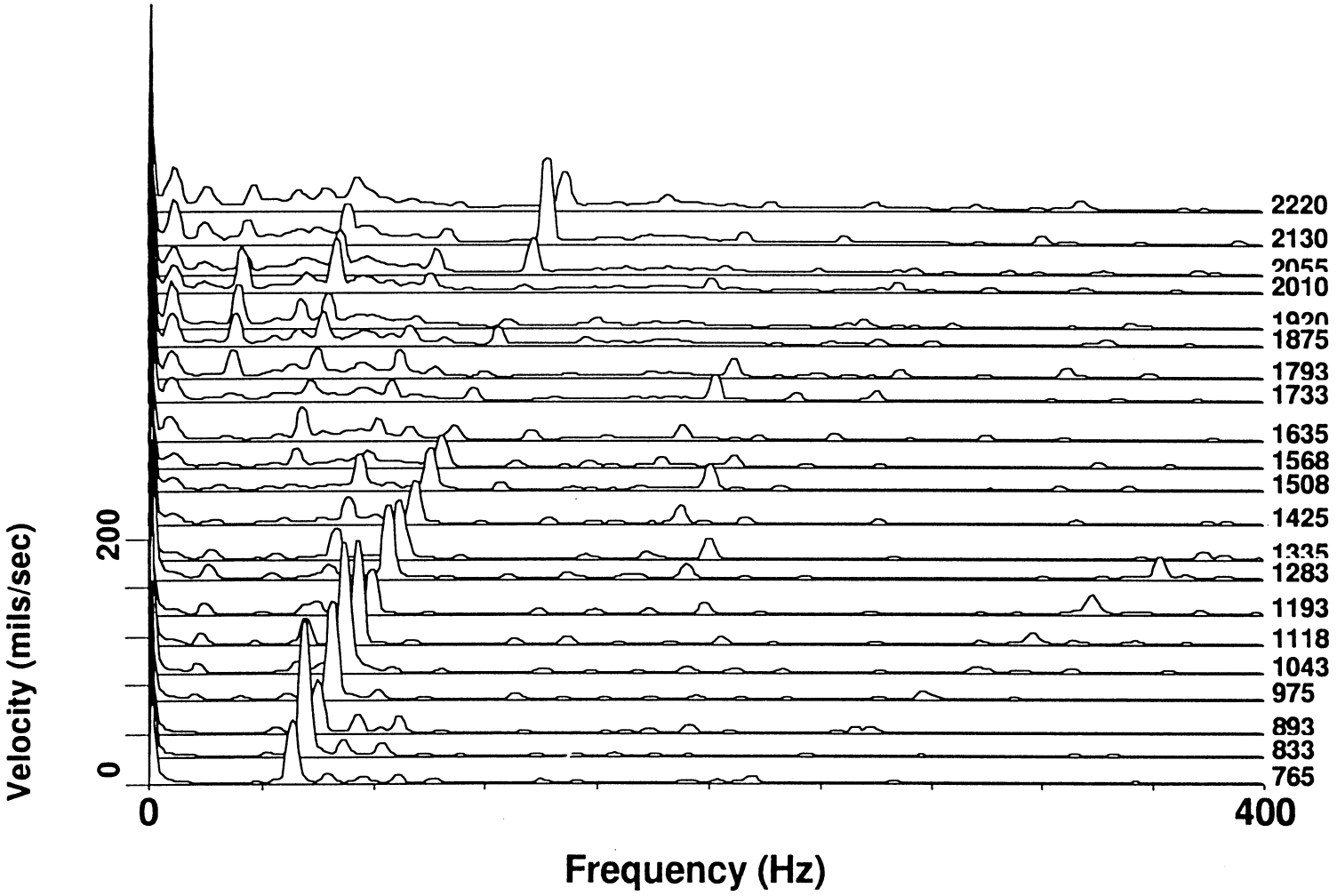
MCF, Hull Stern, Vertical



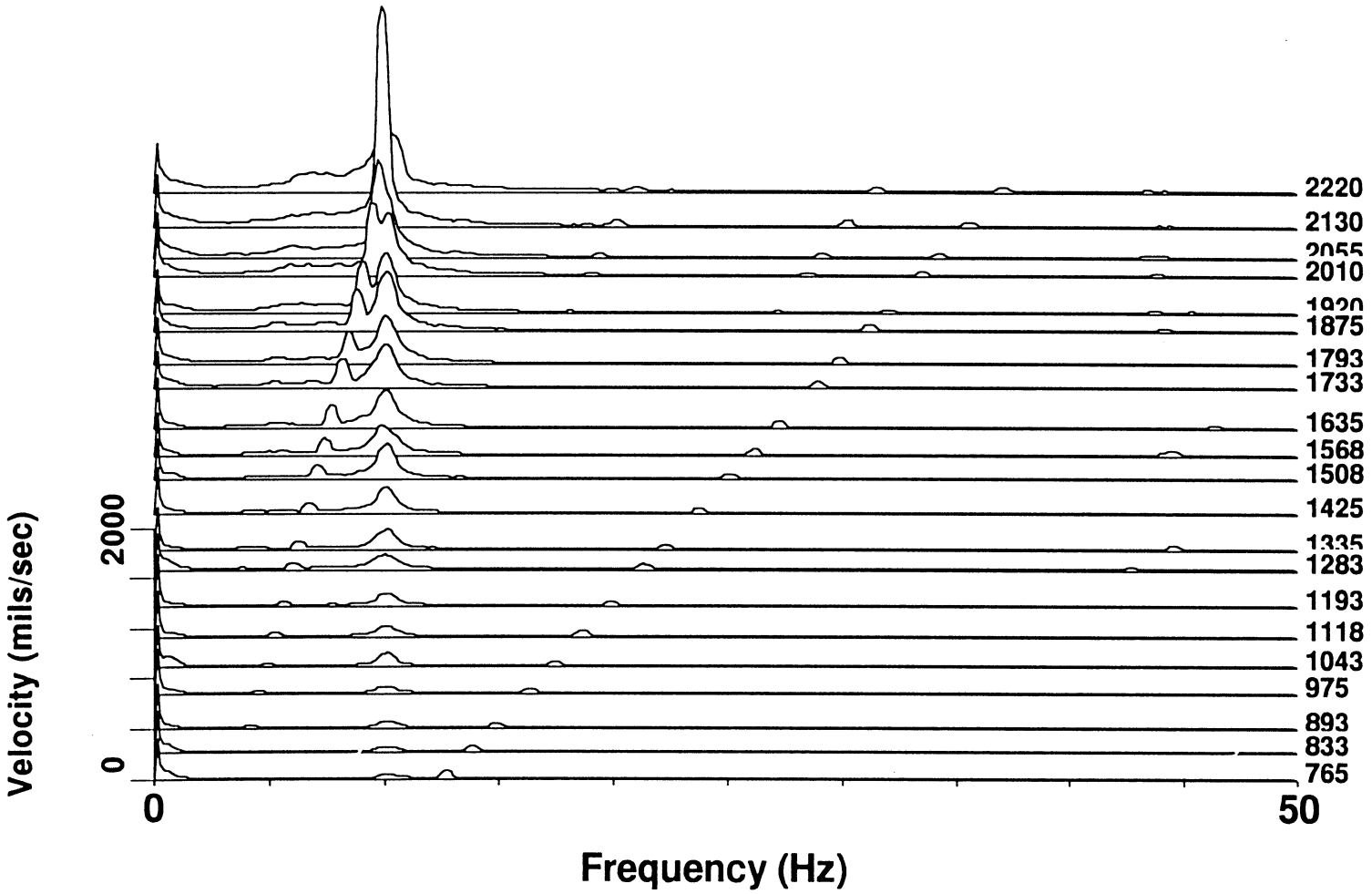
Control Cab, Lower Aft Port Corner, Athwartship



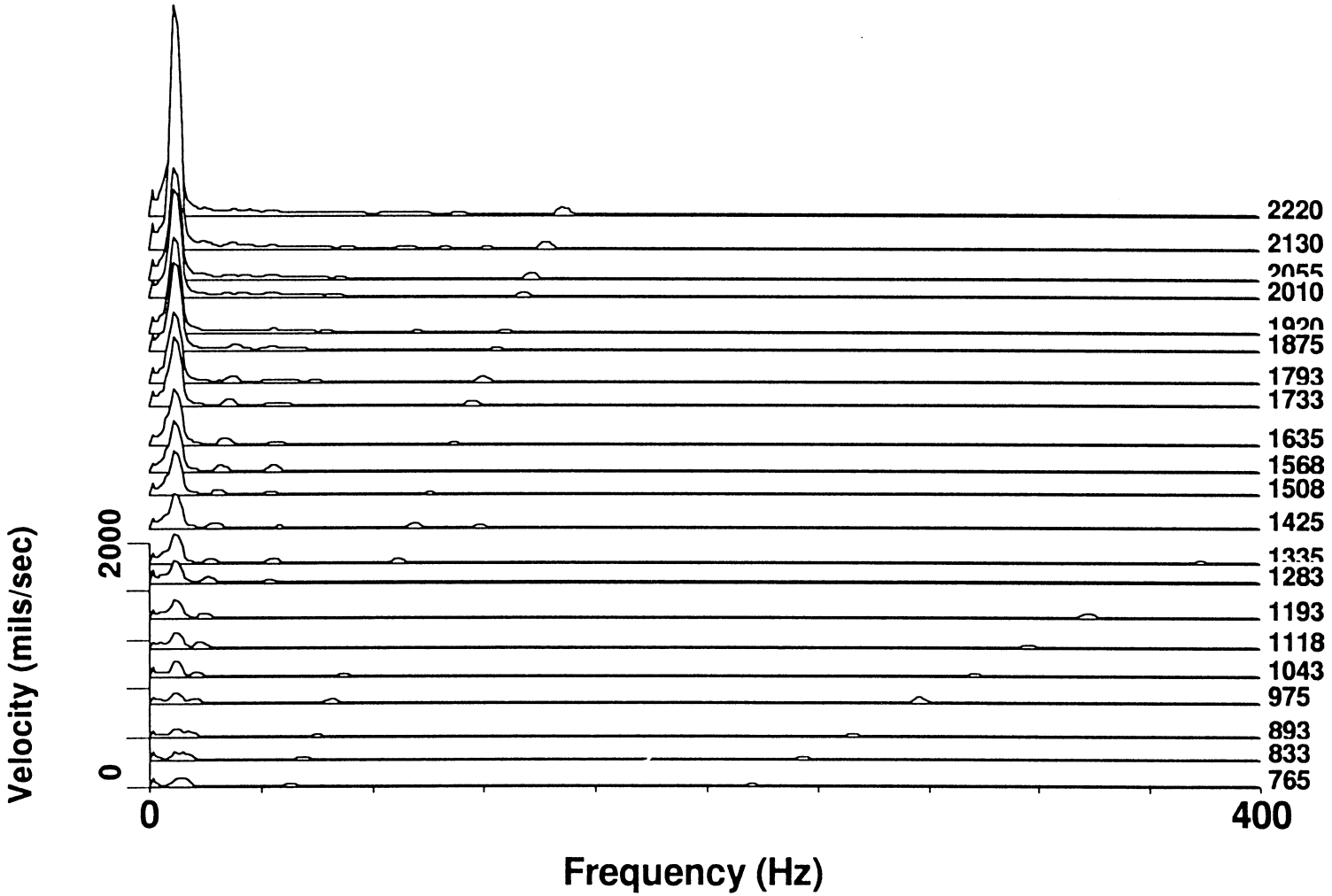
MCF, Control Cab, Lower Aft Port Corner, Athwartship



Top of Water Pump, Athwartship



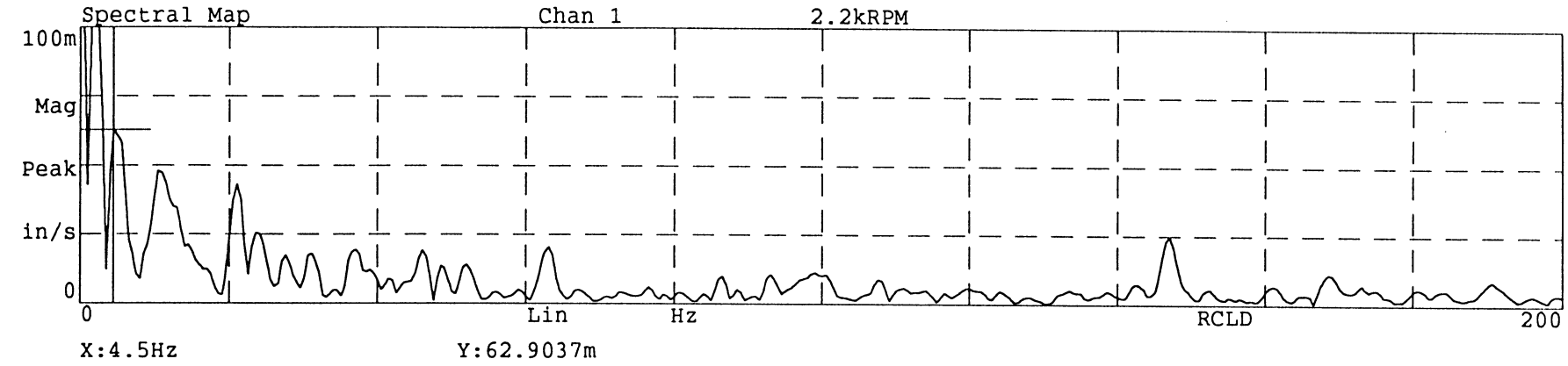
MCF, Top of Water Pump, Athwartship

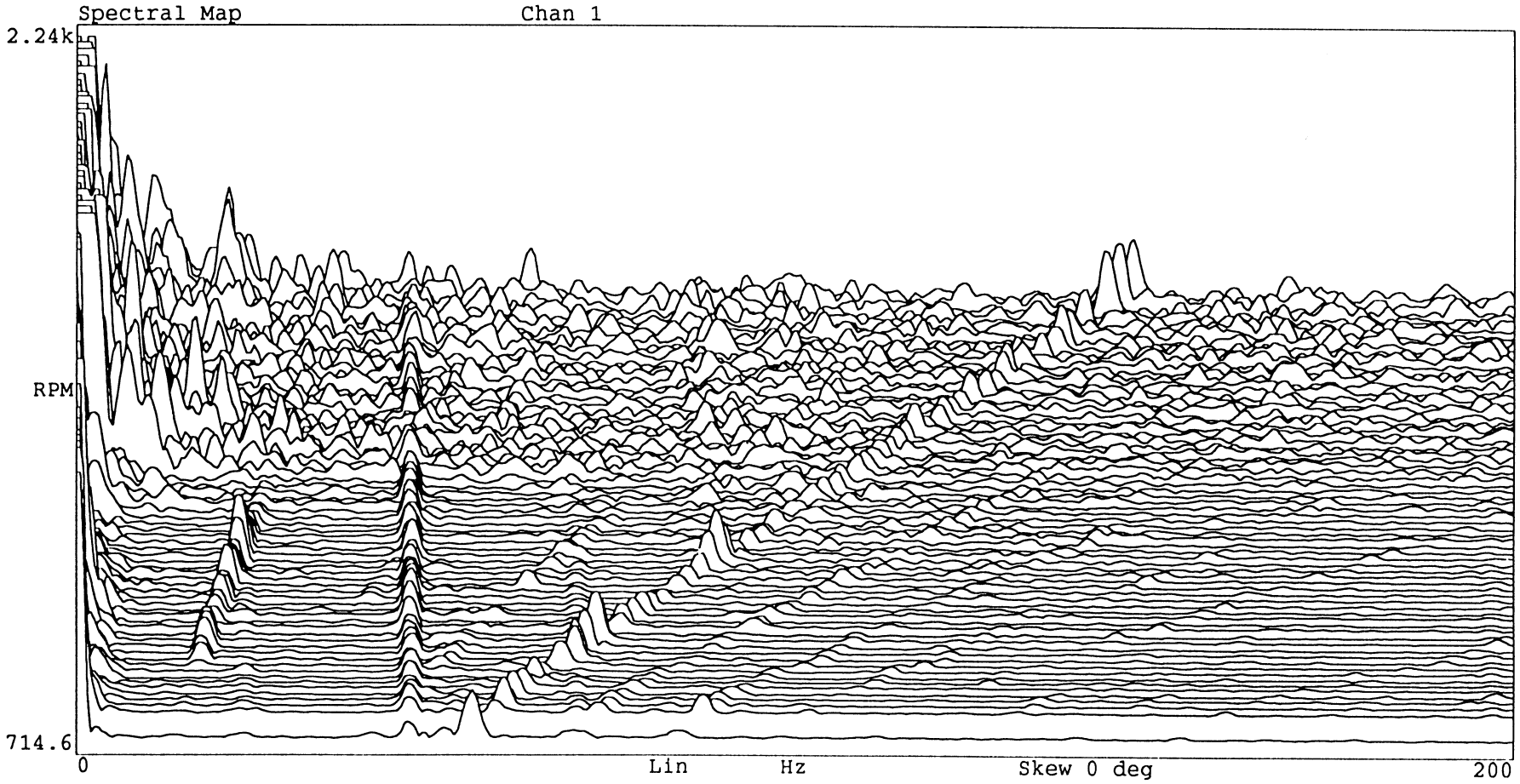


Appendix E

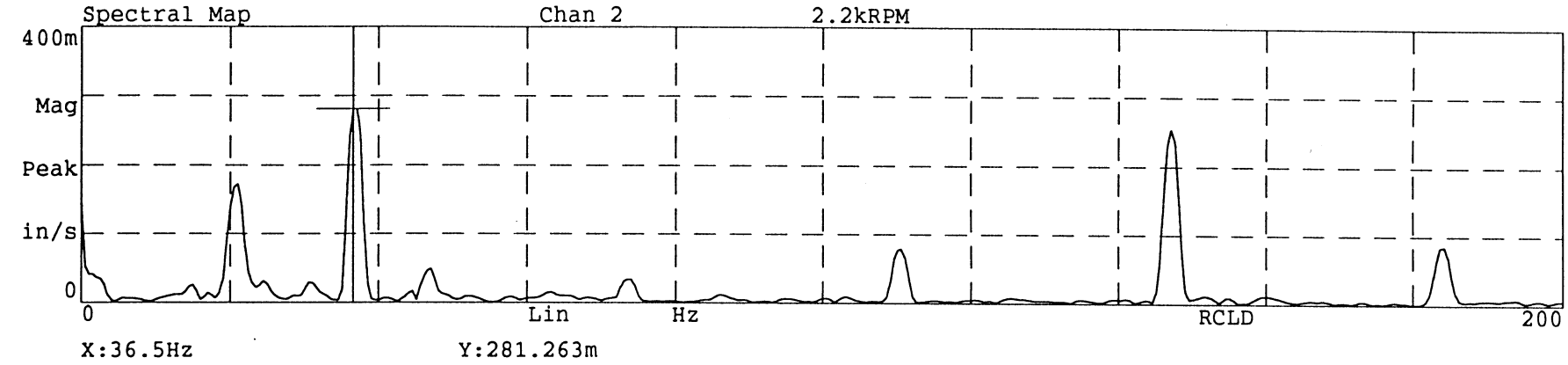
VELOCITY SWEEPS

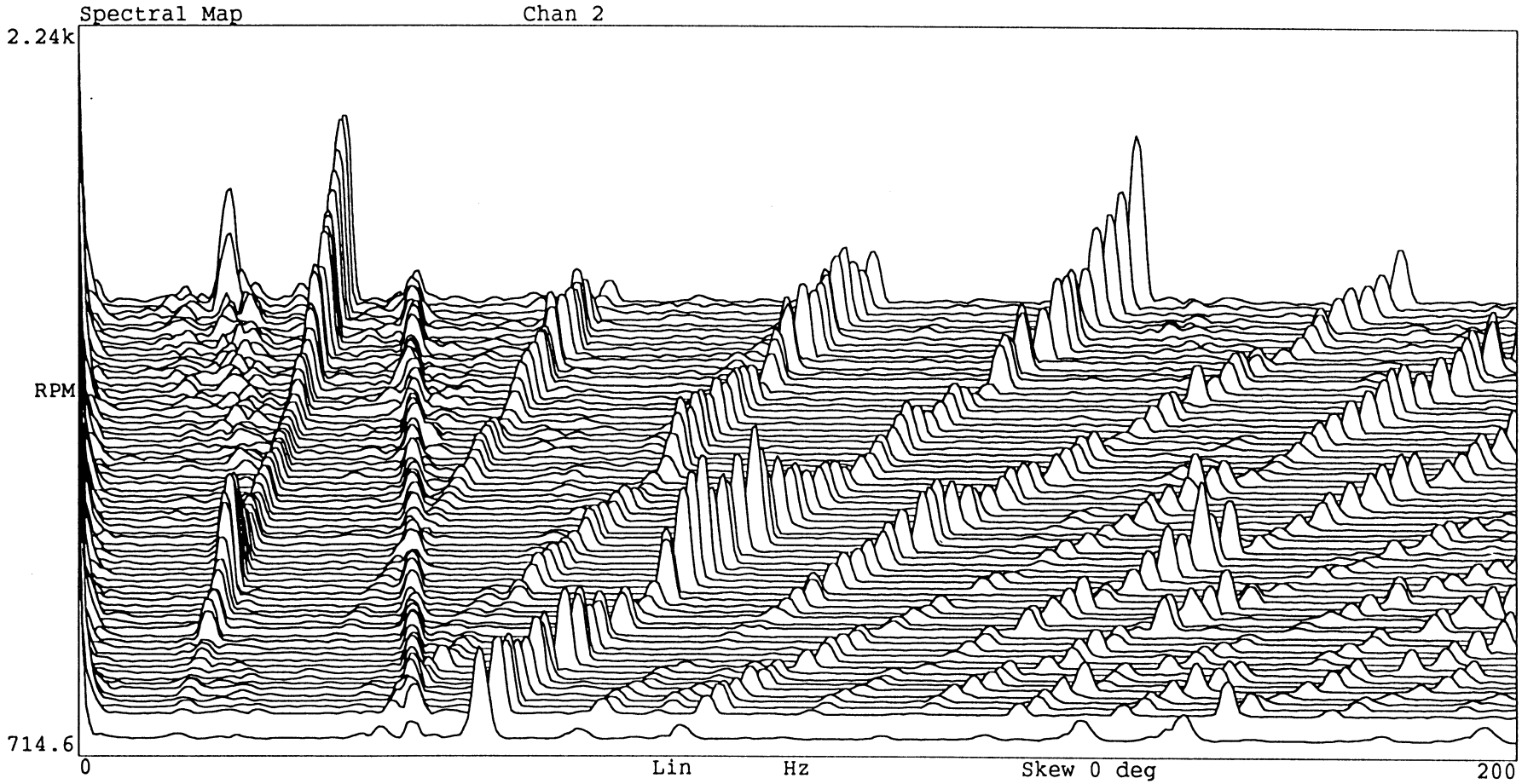
MCF, Base of Waterje (Thruster), Fore/Aft



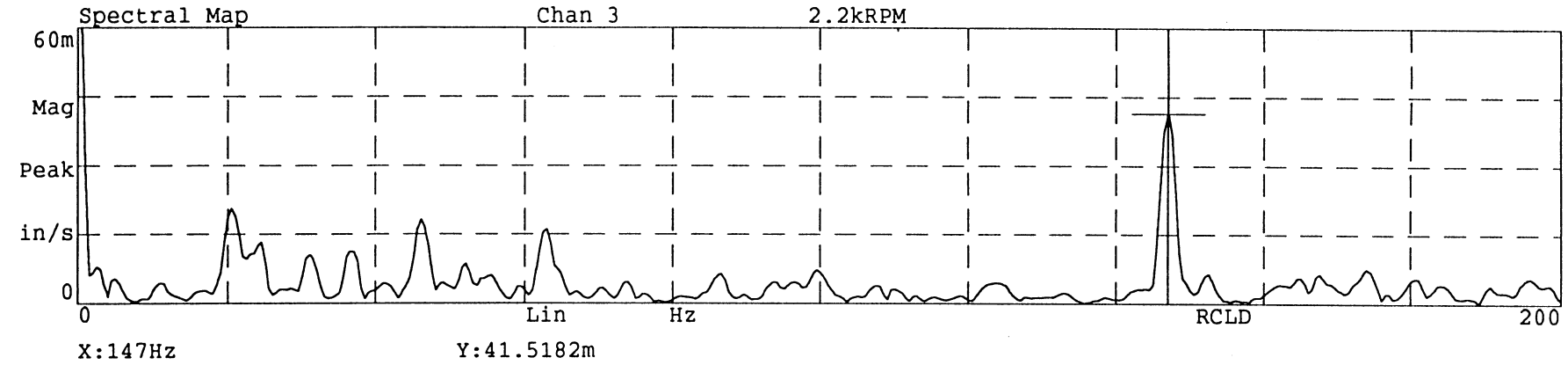


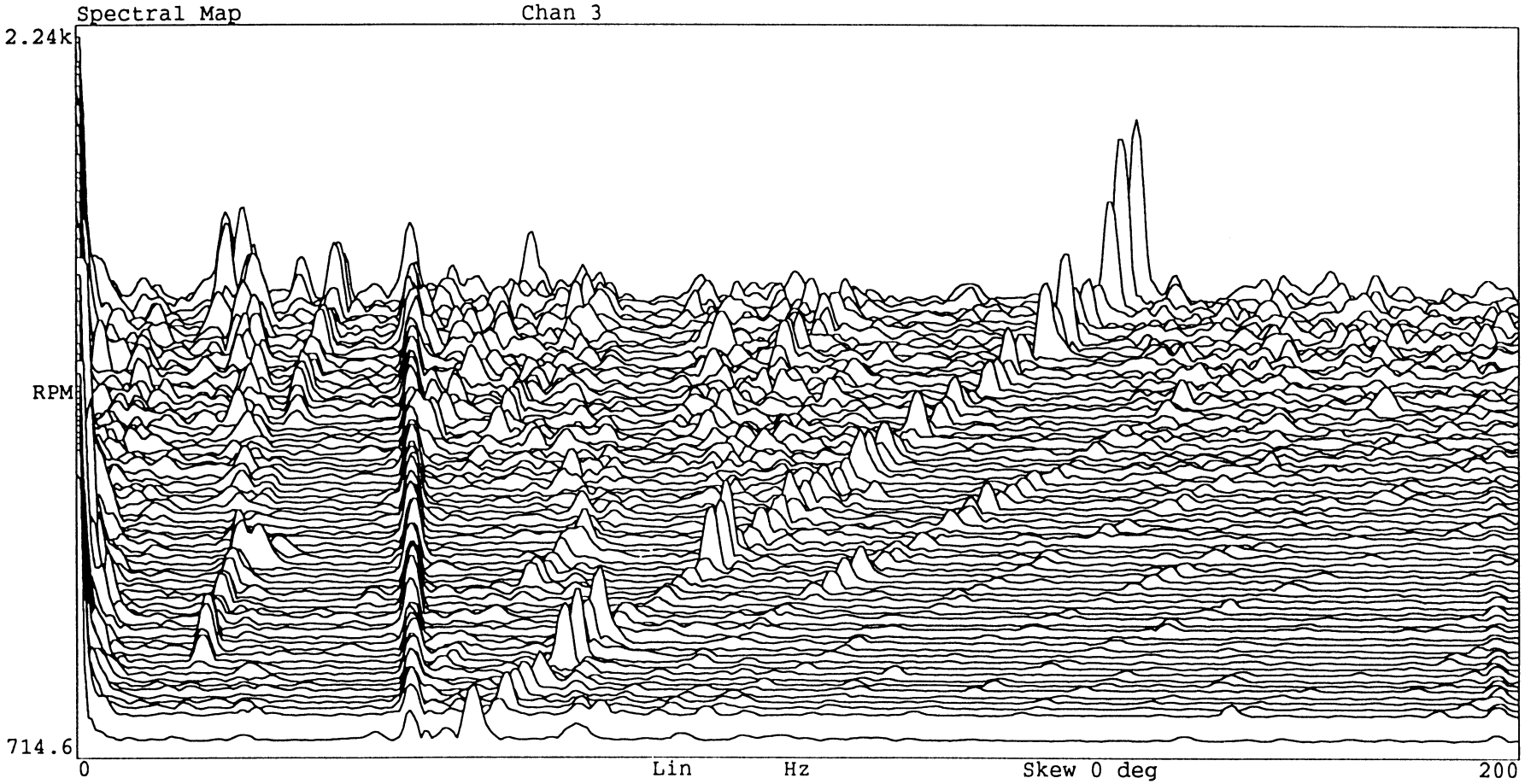
MCF, Base of ;ine, Vertical



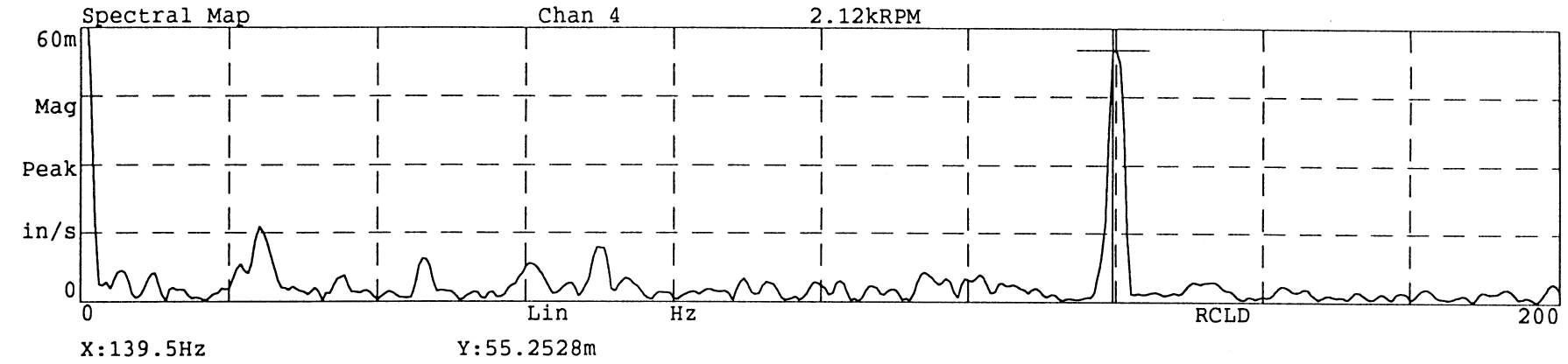


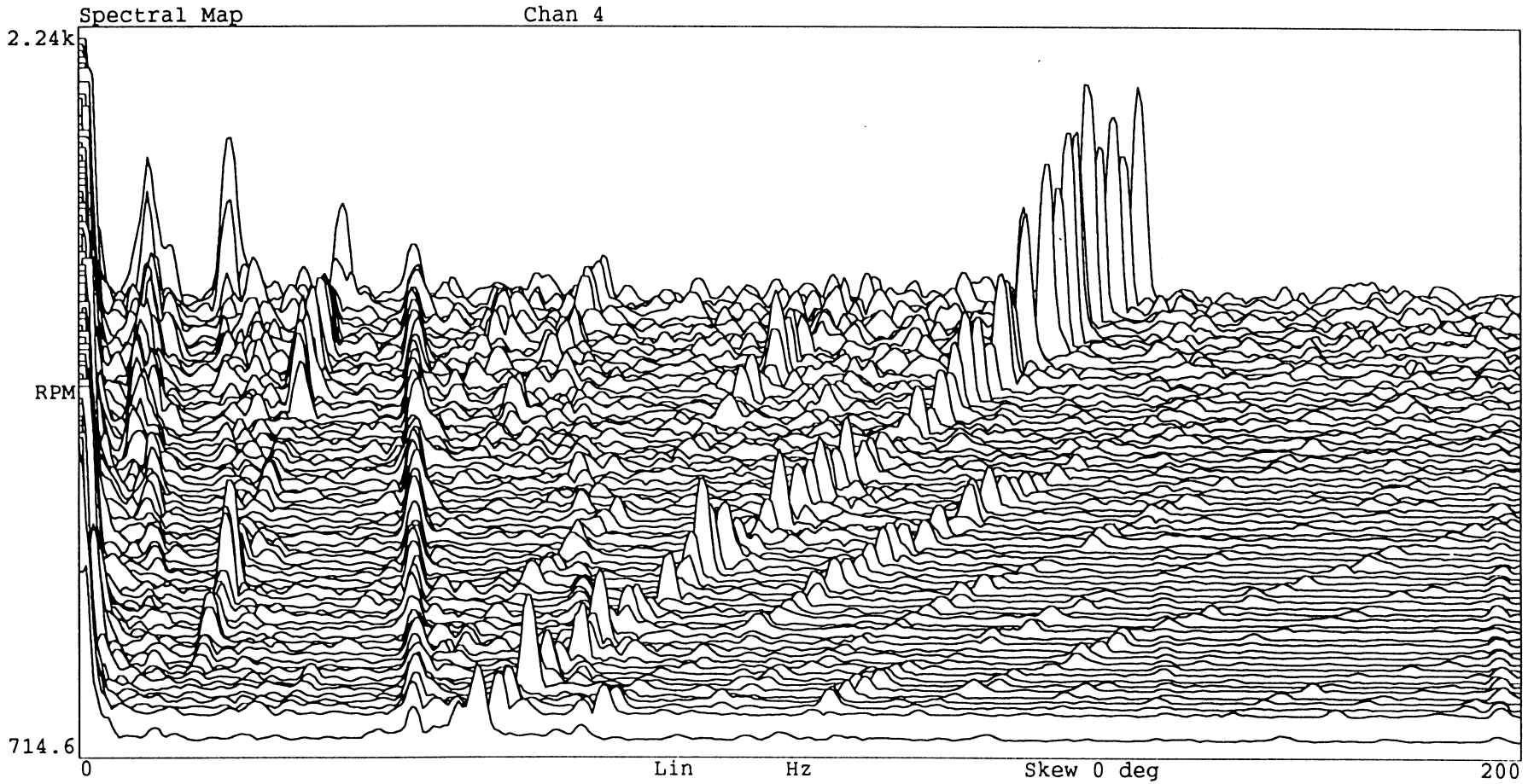
MCF, Hull S[illegible]n, Fore/Aft



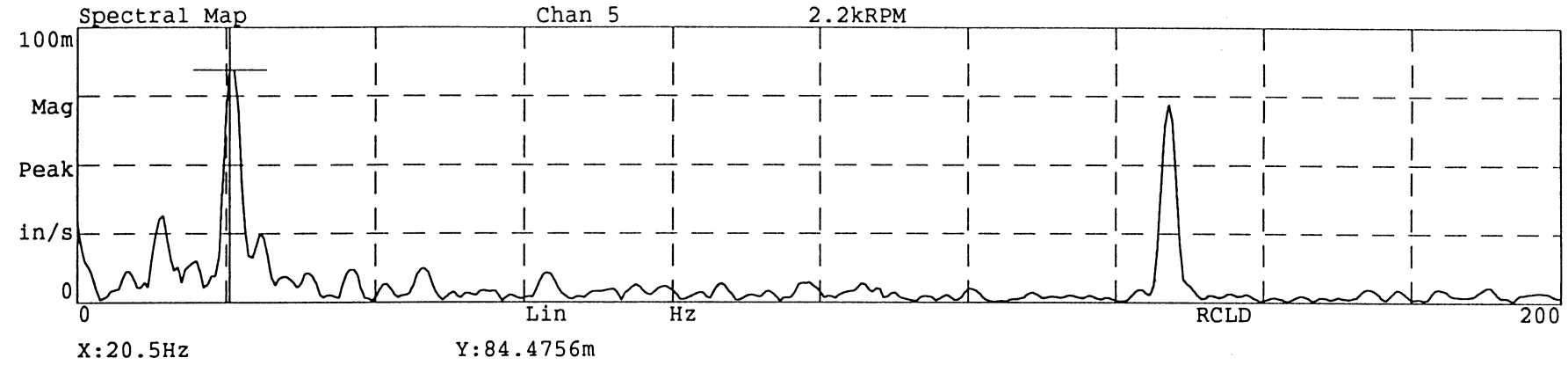


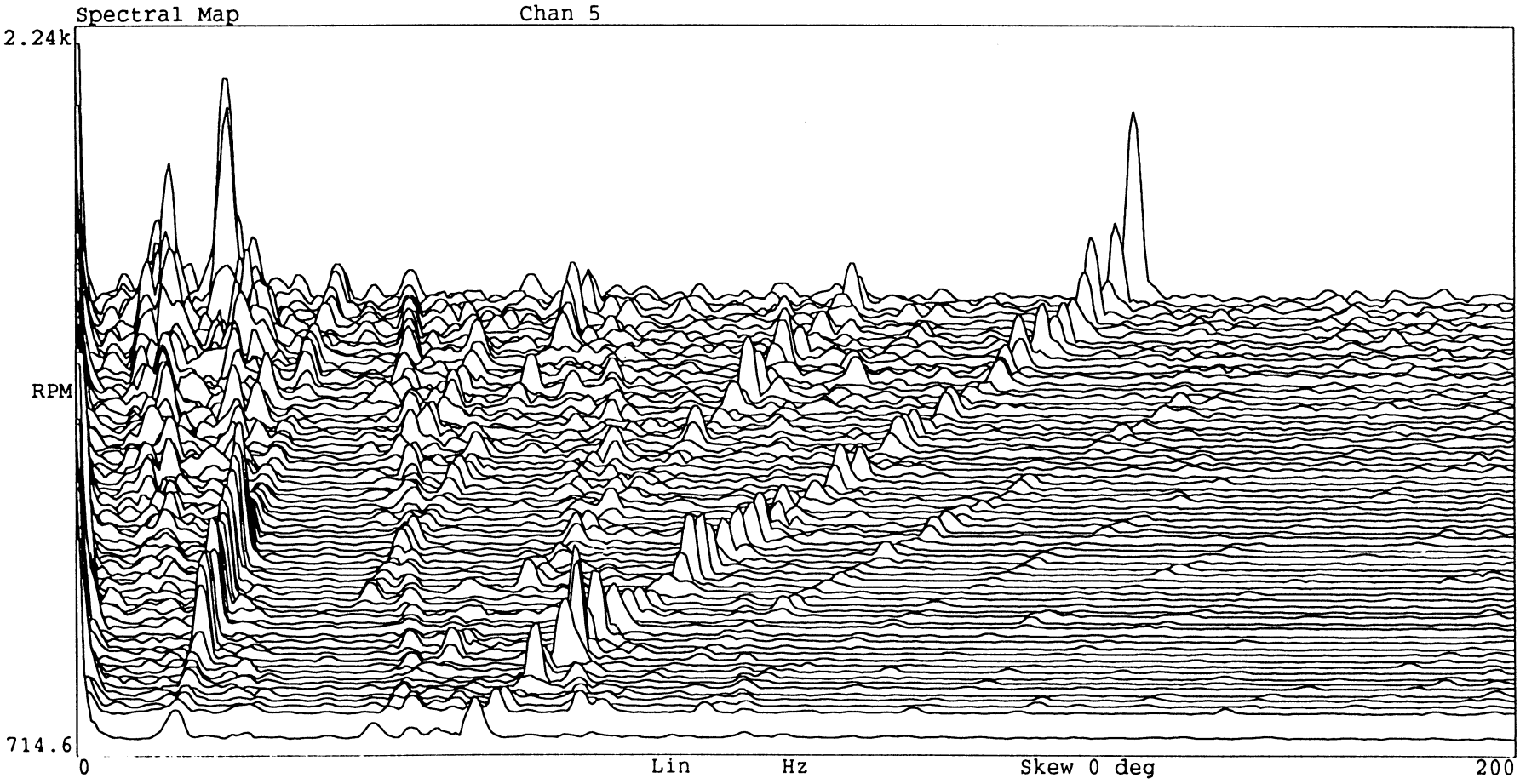
MCF, Hull Ste. , Athwartship



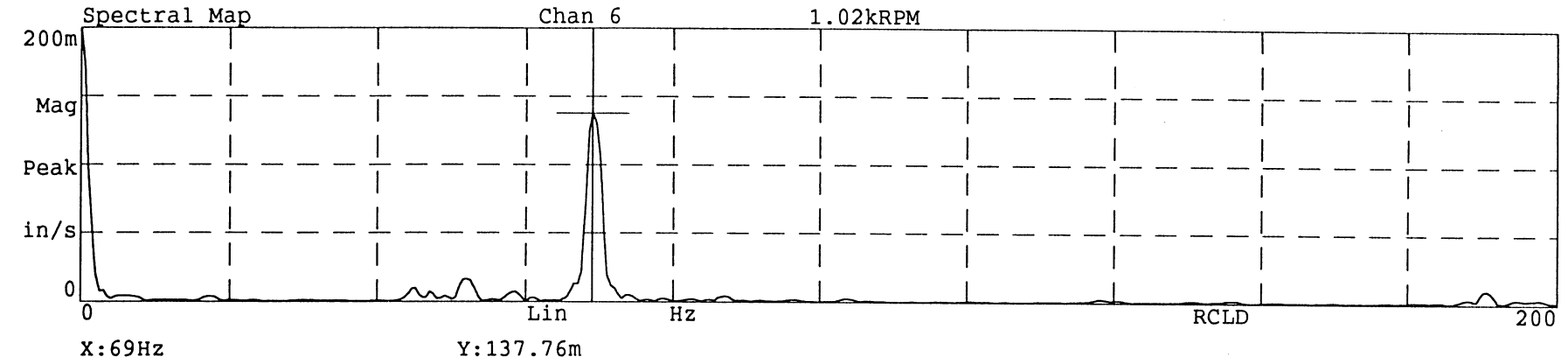


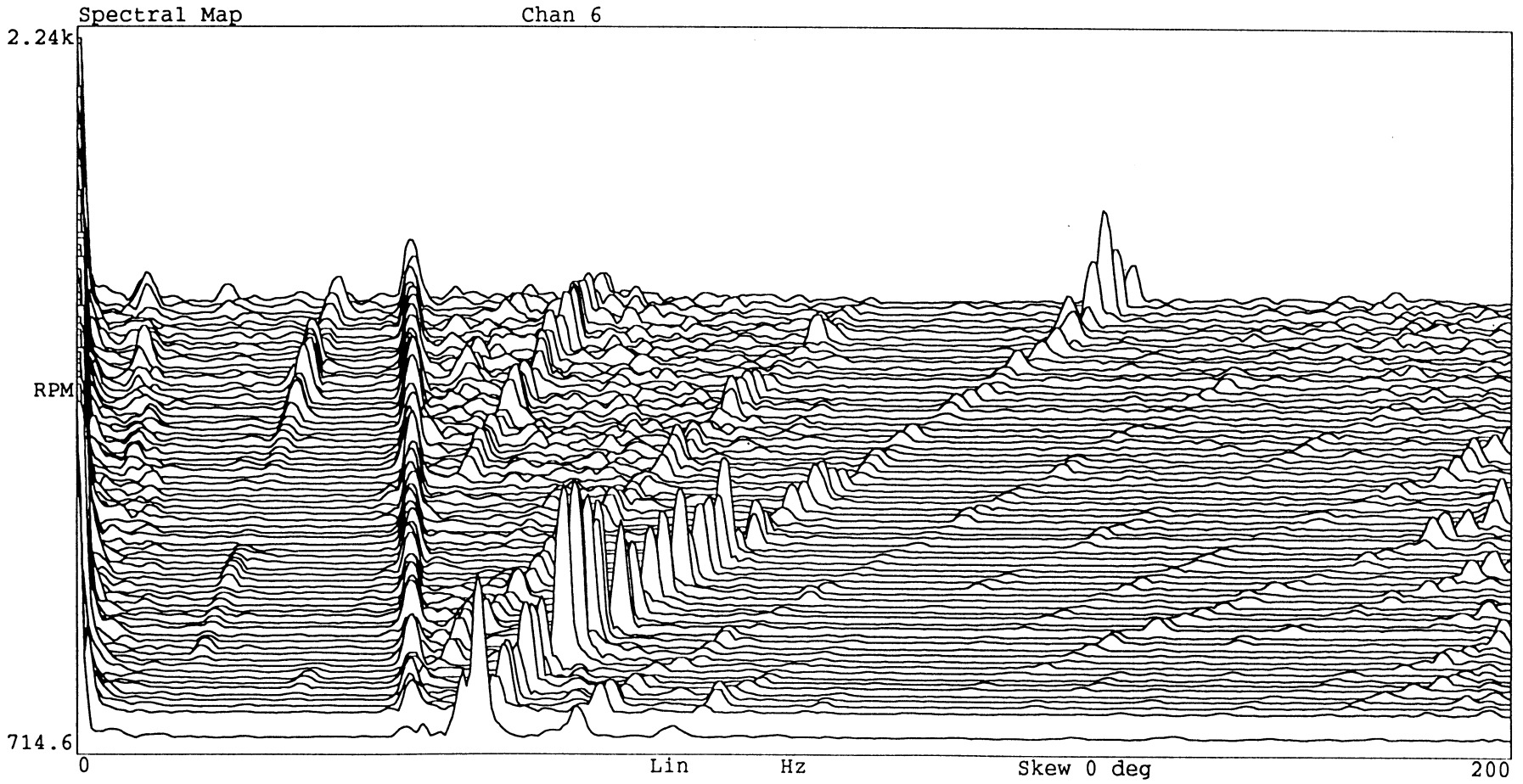
MCF, Hull St n, Vertical



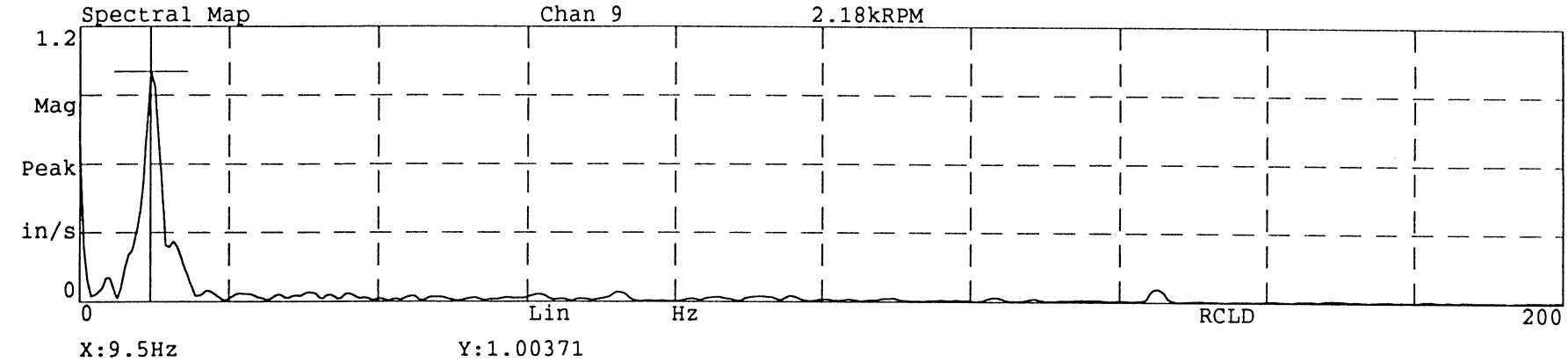


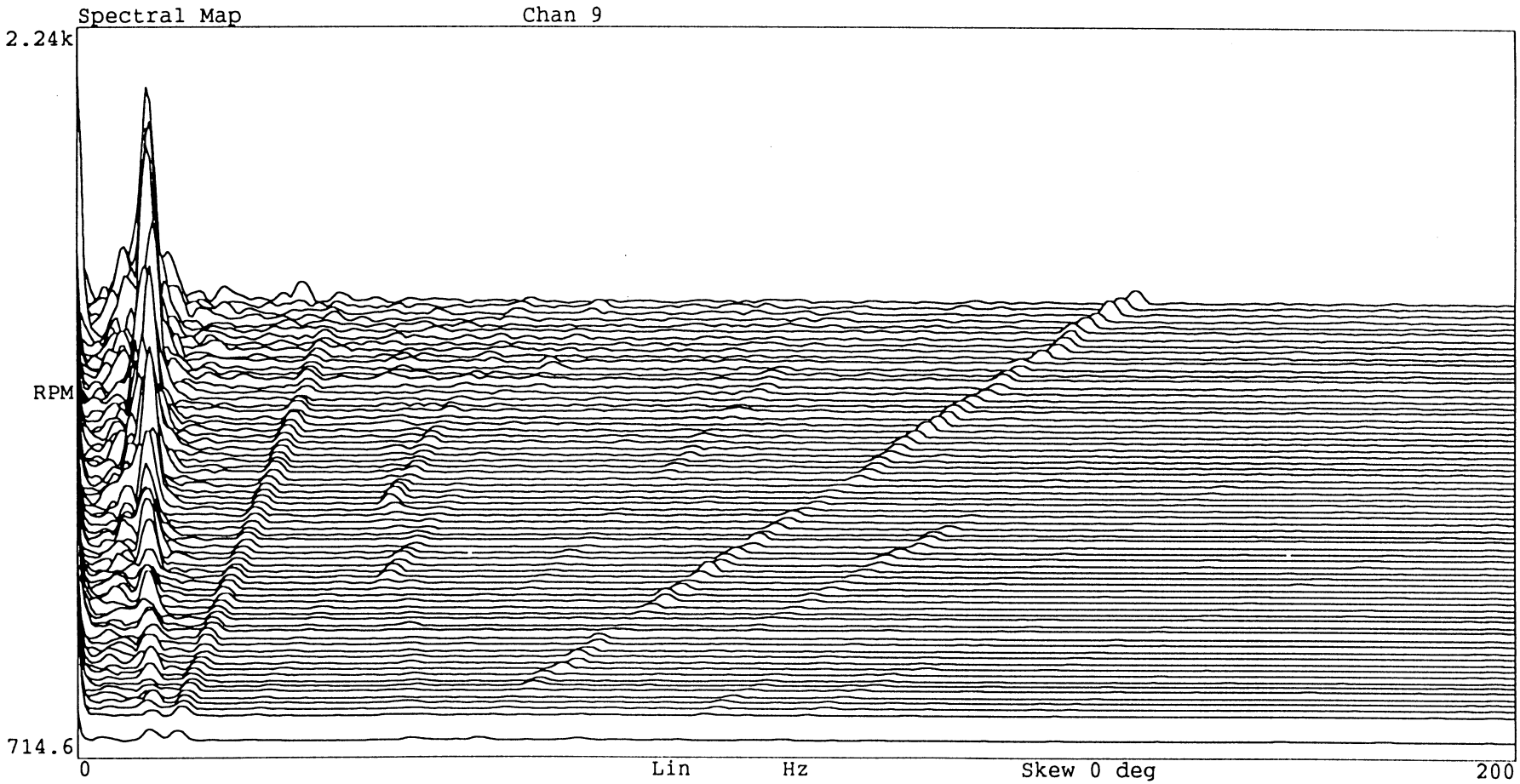
MCF, Control Cab, Lower A Port Corner, Athwartship





MCF, Top of Water Pump, Athwartship

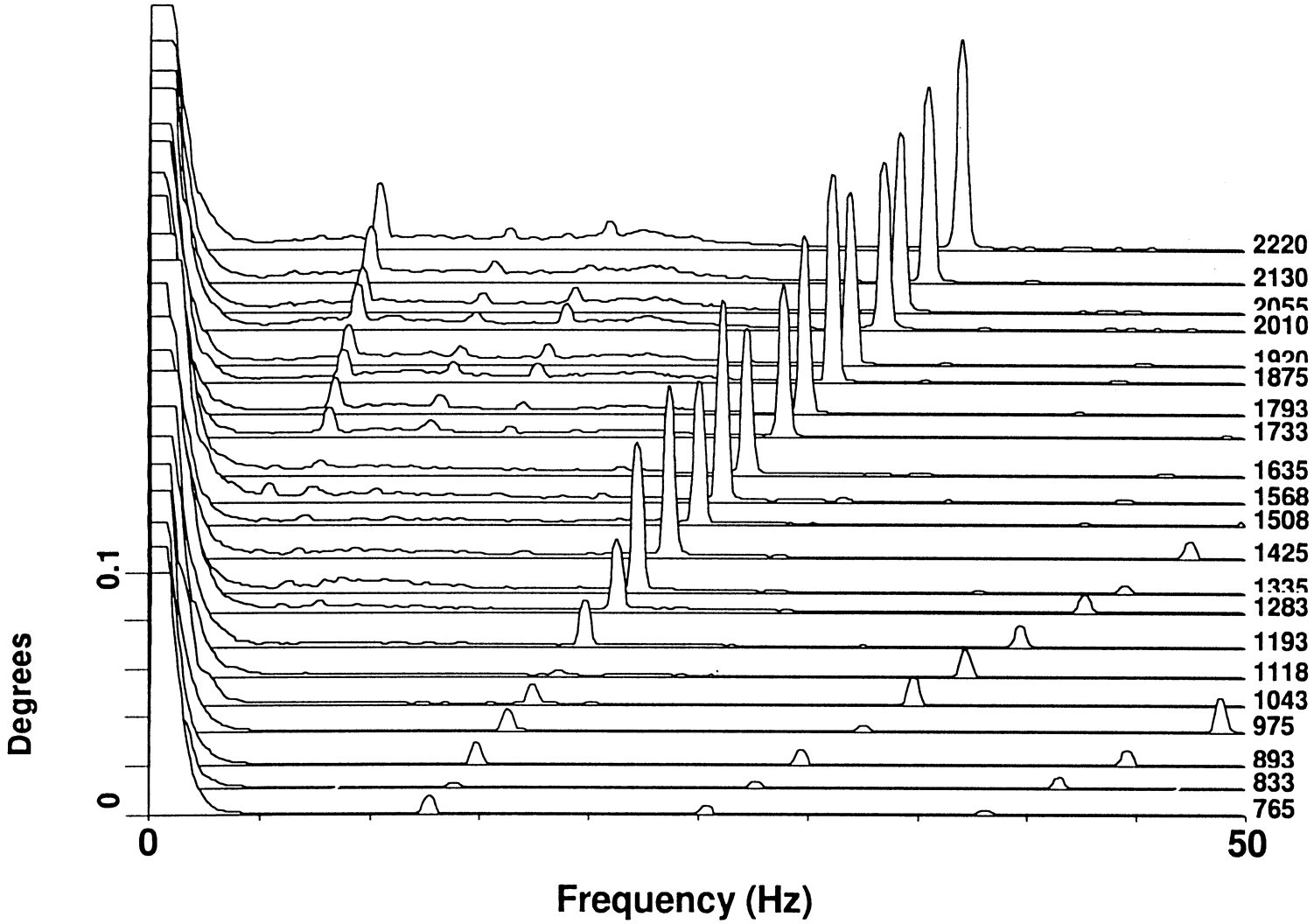




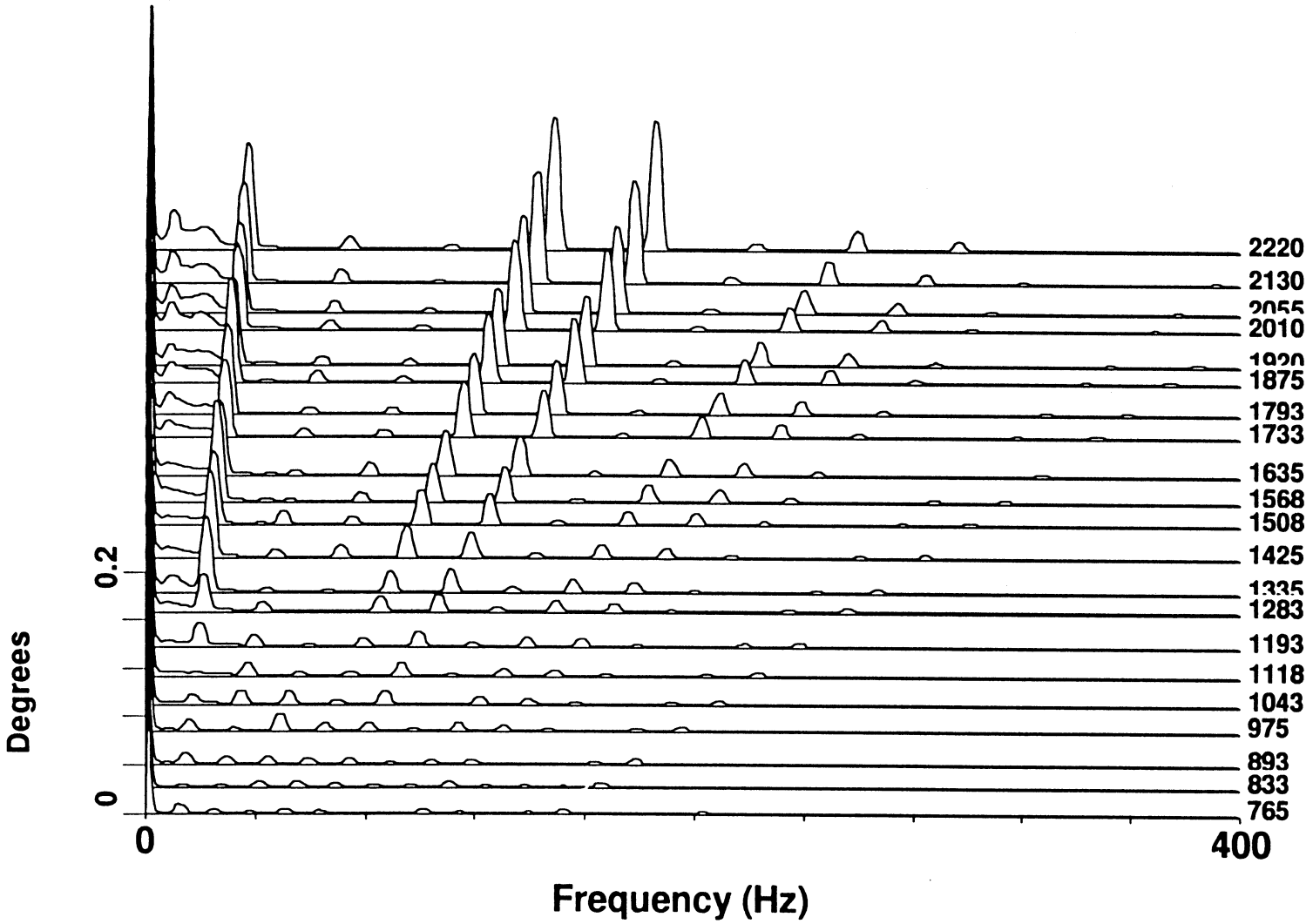
Appendix F

TORSIOGRAPH WATERFALLS AND SWEEPS

MCF, Forward End of Main Engine, Torsiograph (Corr & Int)



MCF, Torsiograph, Fwd End of Main Engine (Corr & Int)



MCF, Fwd End of Mai. ngine, Torsiograph